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THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

MARCH, 1956 Vol. 46, No. 7

BASIC THEORY IN ELECTRICAL ENGINEERING

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ANNUAL MEETING—IOWA STATE COLLEGE
Ames, Iowa June 25–29, 1956

Published monthly (except during July and August) at Prince and Lemon Sts., Lancaster, Pa., by the American Society for Engineering Education under the Supervision of the Publication Committee: W. L. Collins, Chairman, M. M. Boring, N. W. Dougherty, T. Farrell, Jr., G. W. Farnham, M. E. Van Valkenburg, E. A. Walker, E. C. McClintock, Editor. Entered as second class matter, October 17, 1912, at the Post Office at Lancaster, Pa., under the act of August 12, 1912. Accepted for mailing at the special rate of postage provided for in section 132.122, P. L. & R., authorized April 5, 1956. Subscription Price, $6.00 per year; Yearbook Issue, $6.00; Single Copies, $1.25.

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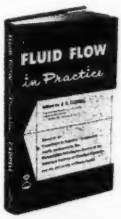

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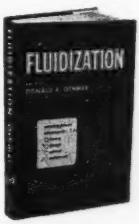

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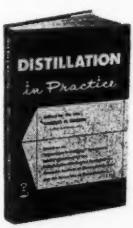

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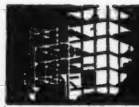

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DO YOU KNOW . . . .

► . . . That in October I stuck my neck out and said one of the aims of the Editor and myself was to get each issue of the Journal to you in the proper month? Well, there were unanticipated troubles! But the worst is over and by May and June we should be on schedule. The goal hasn't been changed but achieving it has been delayed.

► . . . That two new standing committees have been appointed by President M. M. Boring as a result of the meeting of the Society Functions Committee, conferences with members of the General Council, and nine months of experience as president? One is a "top level" Supervisory and Planning Committee. With Thorndike Saville as Chairman, this group includes A. B. Bronwell, L. E. Grinter, S. C. Hollister, B. R. Teare, Jr., and E. A. Walker as members. The purpose of the committee is to look ahead and assist the officers in making future plans for the Society, not to concern itself with present day and every day problems, but to do some "blue sky" thinking and planning. The appointments are for two calendar years and the chairman is to report to the General Council and Executive Board at Annual Meetings.

The second new committee is the Policy Committee, whose function is to advise the President on all matters which he chooses to refer to it. The President of the Society is the Chairman, and the Secretary of the Society is the Secretary of the Committee, without vote. This committee is made up of members of the General Council, half serving one year and the remainder two.

You may ask about the need for these committees. The answer simply is that questions and problems are coming up so fast and are so involved that the President and Secretary of the Society need course and guidance.

► . . . That the increased pace of Society activities also is evidenced by the fact that four items needed to be submitted to the General Council for letter ballot in order to act rapidly and effectively—and in order to comply with the constitutional requirement that the General Council establishes policies? These actions will have to be affirmed at the June meeting of the General Council in order to have the decisions adequately entered in the records. Letter ballots also needed to be sent to the Executive Board on three occasions.

► . . . That at the November meeting of the Executive Board, Vice President F. C. Lindvall stressed the need for better communications with and between Sections and Divisions? The Board agreed that if Sections had liaison representation with Divisions it would be helpful, particularly with respect to the Relations With Industry and the Physics Divisions. The Physics Division requested such liaison. Consequently each Section was asked to appoint a liaison member for the two Divisions mentioned. Liaison with Physics is important. If you have doubts, refer to p. 753 of the June, 1955, JOURNAL and to the "Role of Physics in Engineering" report on page 592 of this issue.

The interest of industry in engineering education, the successful series of College-Industry Conferences, and the increased activity of the Relations With Industry Division in undertaking local programs of cooperation between industry and education also makes liaison with RWI important.

► . . . That at its November meeting the Executive Board voted to approve a budget of $40,000 for the ECRC study of the Research Needs in the Engineering Sciences? Dr. H. K. Work, Vice President of the Society, represents the Board in the solicitation of funds. The proposal has been prepared and submitted to the National Science Foundation for approval.

► . . . That ECRC will have two awards each year for outstanding research. One will be a gold medal (comparable to the Lamme Award) and the other $1000 in cash for a younger man (comparable to the Westinghouse Award)? The sponsors are, respectively, Bendix Aviation Corporation and McGraw-Hill Book Company. The first award of the gold medal will be this year, but the first cash award will be presented in 1957.

► . . . That the total amount of money requested by Division and Committee chairmen has now reached a total of over $1800? Because this amount is increasing so rapidly, because some Divisions want to charge separate dues, and because Sections and Divisions are submitting so few papers for publication in the JOURNAL OF ENGINEERING EDUCATION, the Executive Board requested Vice President L. J. Lassalle to compile the pertinent data for all Divisional publications and then refer the tabulation to the Publications Committee for recommendations. Some of the budgets and plans for publications imply competition with the JOURNAL. The Executive Board unanimously agreed that Divisional or Committee publications must not interfere or compete with the JOURNAL.

► . . . That the Executive Board, at the November meeting, was in full agreement that payment of Divisional dues could not be a requirement for Society membership nor a requirement for attendance at any meetings of the Society or of any of its Divisions?

► . . . That the YET Committee has requested that the sub-chairman for each Section (and a member of the national committee) be selected (elected or appointed) by the Section? The General Council at its November meeting voted that, starting with the year 1956–57, each Section select its own YET sub-chairman, informing the Secretary of the selection as soon as possible after July 1 of each year. Section officers please take note and see that appropriate action is taken before July 1, 1956. The YET Committee is supposedly pressing its membership drive again this year; each institution should have a YET working on this, particularly in related areas such as physics, mathematics, and English. It your representative active?

► . . . That the Summer School for YETs at which pedagogical techniques were to be stressed is not materializing? At its College-Industry conference in Milwaukee, the

Steering Committee of the Relations With Industry Division voted. "That individual companies which were interested in such a program be approached or, conversely, that companies interested contact President M. M. Boring." The plan as proposed was for industry to employ the YETs for the summer, but release them to attend a four-week seminar, the necessary expenses being paid by the employers. Only one "firm" commitment and one "possible interest" developed. The need for this type of training was recognized by all in attendance, but they believed such training was a college problem and that undertaking the plan would impair the hard-won programs now in operation for employment of college teachers.

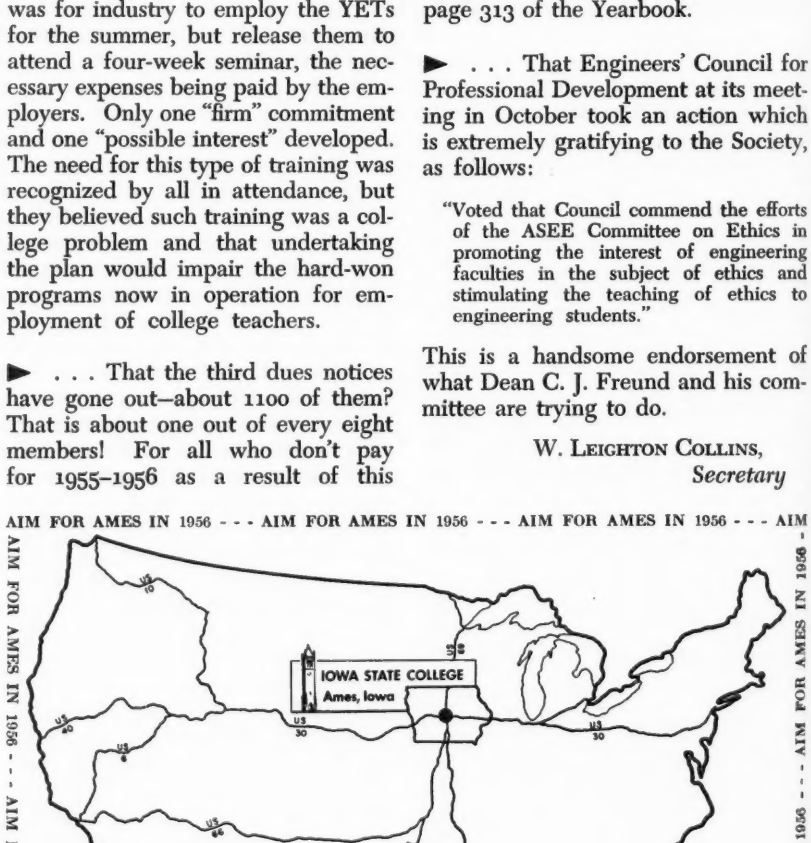
► . . . That the third dues notices have gone out—about 1100 of them? That is about one out of every eight members! For all who don't pay for 1955–1956 as a result of this "dunning," there will be no JOURNALS after June. For those who now owe for two years, the penalty is being dropped from membership by the General Council in June, unless payment is made by July 1. These are the provisions of the Constitution; see page 313 of the Yearbook.

► . . . That Engineers' Council for Professional Development at its meeting in October took an action which is extremely gratifying to the Society, as follows:

> "Voted that Council commend the efforts of the ASEE Committee on Ethics in promoting the interest of engineering faculties in the subject of ethics and stimulating the teaching of ethics to engineering students."

This is a handsome endorsement of what Dean C. J. Freund and his committee are trying to do.

W. LEIGHTON COLLINS,
Secretary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IOWA STATE COLLEGE
Ames, Iowa
US 10
US 30
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GET ACQUAINTED WITH IOWA STATE!

In this issue, ASEE members and their families are given a preliminary view of Iowa State College's lovely campus, and begin their physical orientation for the Annual Meeting. On the following pages are an aerial photograph of the central buildings at Ames, keyed to facing close-ups of the focal points from which Society activities will radiate. It is hoped that with this combination ASEE visitors will have at least a few points of reference to find their way about and to recognize the starting blocks of their stay.

These might well begin with the Memorial Union Building, the hub of Society activities, in the center just north of eastwest highway 30. The Union lies directly between the men's residence halls (Friley-Hughes) two blocks to the west, and the women's residence group, about the same distance to the east, reserved for ASEE couples and families.

If you're a single man you'll take up your quarters in Friley-Hughes Hall, the home of 1,420 male students when filled to capacity during the regular college year. Its 640 rooms make it one of the largest student dormitories in the nation. Actually, Friley-Hughes is a succession of buildings, comfortably knit together into a harmonious structure which sprawls along more than two blocks of winding campus road and busy highway. Hughes Hall was erected in 1927, the first section of Friley Hall in 1939. Additions to Friley were built in 1942, 1951, and 1954, the final one serving to connect Friley and Hughes into the present mammoth structure. The combined hall bears the names of Dr. Raymond M. Hughes, president of Iowa State from 1927 to 1936, and Dr. Charles E. Friley, who guided the College from 1936 to 1953.

Meals will be served cafeteria style in the hall's west commons, seating 336 persons, and in six private dining rooms which can be arranged for groups varying in size from 24 to 120. The dining areas which members of the ASEE will use are part of the most recent construction program, and practically all are air-conditioned.

About four blocks east of Friley-Hughes Hall is the main group of women's residence halls, which will provide quarters for ASEE couples and families. Of eight halls clustered around a courtyard and semi-circular drive, seven will be reserved for those attending the Annual Meeting. Five units will accommodate 330 couples, and two will house 130 families. The first of the women's group was built in 1915, the last in 1940, and a large new unit is currently being constructed to complete the plan.

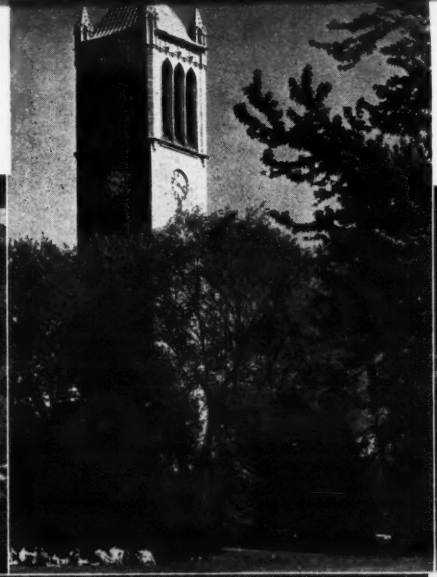
Midway between the men's and women's residence accommodations is the Memorial Union, which will serve as convention headquarters. The handsome limestone building was first occupied in 1928, but additions in 1936, 1939, 1949, and 1953 have greatly extended its size and usefulness. Still another expansion is planned within the next year. In the Union you'll find a spacious lobby, women's lounge, men's lounge, and a general television-watching lounge—all air-conditioned.

The Union is very proud of its food

Aerial: General view of Iowa State College, looking north from Ames. East-west transcontinental highway, route 30, is in foreground. The focus of ASEE interest and activity will be (1) the Memorial Union. To left (2) are the men's residence halls, to right (3) the women's residence group. Building (4) is Marston Hall, headquarters of the Division of Engineering, and (5) is the

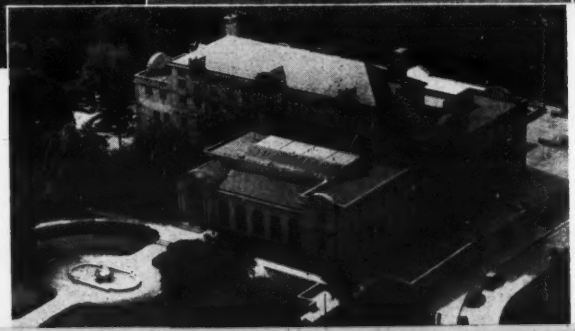
Aerial: General view of Iowa State College, looking north from Ames. East-west transcontinental highway, route 30, is in foreground. The focus of ASEE interest and activity will be (1) the Memorial Union. To left (2) are the men's residence halls, to right (3) the women's residence group. Building (4) is Marston Hall, headquarters of the Division of Engineering, and (5) is the

Below—Men's Residence Halls, Friley-Hughes, assigned to ASEE bachelor visitors —the west pole of the campus east-west axis.



Left—The Stanton Memorial Carillon, landmark of the Ames campus, and the source of musical background for the convention.

Right—The Memorial Union of Iowa State College, ASEE Headquarters for the sixty-fourth Annual Meeting.



Above—A unit of the Women's Residence Group, assigned to married couples and families of ASEE members.

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(This view is from the northwest, with cars entering the access road from route 30 behind the building.)

services, and offers attractive meals at moderate prices. The air-conditioned cafeteria and general commons room is a good place for breakfast, luncheon, or dinner, as well as an ideal spot for a cup of coffee and stimulating conversation between sessions. The air-conditioned Oak Room provides meals with table service. Some of the ASEE dinners and luncheons will be held in the Great Hall and South Ballroom of the Union. The many special meeting rooms will be scheduled for ASEE sessions throughout the convention.

To supplement the lounging areas, the "active" recreational facilities of the building include fourteen bowling alleys, a table tennis room, and a billiard room, all air-conditioned.

You'll be pleasantly surprised at Iowa State's uncrowded, uncluttered campus. Transcontinental Highway 30 marks its southern edge, along the residence hall area, but nowhere does a main highway cut through the College grounds. The prairie was broad when the first quadrangle was laid out, and even today the 845 acres of main campus and recreation areas are not filled.

Generally speaking, the college buildings are grouped around a large open rectangle which forms the central campus. Along the west side of the rectangle are most of the engineering facilities. Agriculture occupies the east side, with Home Economics, Science, and Veterinary Medicine along the north. Men's and women's residence groups, the Memorial Union, and the atheletic stadium form the south border.

As you stroll along pleasantly-shaded walks you'll hear the music of the Stanton Memorial Carillon. Housed in a 110-foot tower near the center of the campus, undisturbed by echoes, it is considered among the best musical instruments of its kind. Each morning hymns are played by the carillonneur just before 8 o'clock. A program of college songs, classical music, and selections written especially for the carillon is played at 1 o'clock in the afternoon. Visitors may climb the tower to the room in which the keyboard is located, and watch the carillonneur during his programs.

The first scientifically tuned chime of bells to leave Europe, the Iowa State group was imported from the John Taylor and Company foundry in Loughborough, England, and placed at Ames in 1899. A quarter of a century later, 26 more bells were acquired, changing the chime of ten bells to a carillon of 36. This spring another thirteen bells are to be added.

Perhaps you'll also want to investigate the College Library, which has placed special emphasis on the development of complete scientific and technical journal files for both basic and applied fields in the physical and biological sciences. The Library's holdings in these areas rank favorably with other important research collections of this country. As of June, 1955, the collections numbered 451,444 accessioned volumes of books; 8,311 serials, including 2,732 journals, are currently received.

Most of the library services are concentrated in the main Library Building to the west center of the campus, but special collections are maintained for engineering, architecture, economics and sociology, and animal husbandry. Each of these is located conveniently to serve the staff and students concerned.

In addition to the engineering buildings, the facilities for home

economics and agriculture deserve visits on the main campus. Beyond these, the Experiment Station, the Ames Laboratory of the Atomic Energy Commission, and the Institute for Atomic Research head the list of interesting technical possibilities for exploration. Resources nearby for both entertainment and exercise are available as well. Those who exhaust these early, however, are invited to visit (either for a stroll or for a few hours to play a round or two) the College golf course at the northwest corner of the campus. Rated as one of the best in the Midwest, the opening holes of the course can be seen at the upper left of the aerial scene.

Above—A fairway of the Iowa State College golf course;

Right—A cafeteria scene in the men's residence halls.

AIM FOR AMES

June 25-29

By Air - By Bus - By Rail - By Car

Remember — Reservation to Room

110 Marston Hall, Ames, Iowa

ASEE 64th ANNUAL MEETING

SURVEY OF INSTRUCTION IN ENGINEERING MECHANICS

G. WALLACE SMITH

Head, Department of Engineering Mechanics
North Carolina State College, Raleigh

Presented at Annual Meeting of ASEE
Mechanics Division, The Pennsylvania State University
June 23, 1955

All degree curricula in engineering usually require that an understanding be acquired of: (1) the types of motion that occur in solid or fluid bodies; (2) the forces that act upon or affect the motion, equilibrium, and stability of the materials used in engineering construction, design, or field operations; (3) the basic laws that govern the proportioning and selection of materials to resist effectively the action of forces or utilize forces to best advantage.

The courses generally included in engineering mechanics for an undergraduate curriculum are divided into four major topics, and are intended to integrate and amplify the ideas developed in earlier mathematics and physics courses. These topics are: statics, dynamics, fluid mechanics, and strength of materials, with fluid mechanics and materials testing laboratories. Each of these topics places emphasis on the development and theory of the basic concepts that an undergraduate student should acquire for further use in his particular curriculum. The courses of engineering mechanics have as an additional objective the development of analytical skills and insights required in the solution of engineering problems.

Although these subjects are generally considered to be fundamental, the extent to which they are included in the several engineering curricula seems to vary. Even a single subject, such as statics or dynamics, would be presented with a different degree of emphasis for different curricula in the same school. This variance of subject material and time allotted for its presentation was so interesting that a study was made to try to find the degree to which the engineering mechanics courses were included in the various curricula of a large number of schools that are recognized by the Engineers' Council for Professional Development.

The data used in this study were obtained by examining the curricula of the engineering schools as given in their catalogs for the session 1953-1954. The fourteen curricula selected for this study were those most generally offered and accredited by the ECPD. All of the data obtained were tabulated and then sent to the respective engineering schools with a request that they check the accuracy and supply any additional information then available.

Information was finally obtained from 122 schools for a total of 746

curricula, varying from very large to comparatively small enrollments. In some schools there were many different curricula, in others there were only a few, and in three schools only one. Some of the schools were on the standard four-year plan, some on a five-year plan, and others were following cooperative plan. Because most of the schools were on the semester system, the data given for the term system were adjusted to the equivalent time of the semester system.

The data as assembled were useful in making a number of analyses, but it was decided to restrict the results of this study to the summaries given in Tables I through III.

No attempt has been made to form any conclusions from this study. The prime motive has been to present the facts so that any school or curriculum could compare its mechanics requirements with those generally indicated in this article. Each reader may form conclusions, which may vary widely to fit the particular interests or needs of a school, curriculum, or location.

Making the study has been interesting, however, and it is hoped that the results will be informative and useful to others as well.

General Information

The electrical engineering curriculum is used as an example to explain the general information given in Table I.

a. 115 of the 122 schools studied offered a degree in Electrical Engineering, 113 of which were accredited by the ECPD; 88 of these schools were on the semester system.

b. This curriculum indicated that statics was most frequently scheduled in the second year, second semester, after there had been scheduled an average of 5.32 semester hours of calculus and 5.85 semester hours of physics. The average has been mentioned here, but the table also indicates the extremes. Averages will be indicated hereafter, but the extremes can always be found in the table.

c. All of the schools scheduled statics, with an average semester requirement of 2.74 semester hours.

d. 114, or all but one of the schools, scheduled dynamics with an average requirement of 2.72 semester hours. Sixteen of these schools, however, scheduled a one-semester course to include both statics and dynamics, with an average requirement of 4.12 semester hours.

e. 113, or all but two of the schools, scheduled strength of materials, with an average requirement of 3.27 semester-hours. Of these schools, 20 required a laboratory course as part of the semester-hour credit, and 51 schools gave a separate materials testing course with additional semester-hour credits.

f. 74 schools scheduled fluid mechanics, with an average requirement of 3.00 semester hours, and 30 of these schools included a laboratory with the course.

g. The average number of semester hours scheduled for all mechanics courses was 11.27 hours, or 7.62 per cent of the total semester hours required in an average electrical engineering curriculum.

The information furnished in Table I is quantitative; that is, it gives the amount of time scheduled or allotted to the respective mechanics subjects in relation to other topics and the total curriculum. Some phases of the mechanics courses cannot be put in tabular form, such as the quality of

TABLE I

SUMMARY OF DATA FOR BASIC ENGINEERING MECHANICS COURSES SCHEDULED IN A NUMBER OF ENGINEERING CURRICULA

122 Schools Included			Aeronautical	Agricultural	Architectural	Ceramic	Chemical	Civil	Electrical	Physics	Geological	Industrial	Mechanical	Metallurgical	Mining	Petroleum	Total All Curricula
Number of Curricula		Included in Analysis	46	32	25	14	94	118	115	18	18	60	116	43	28	19	746
		Accredited by ECPD	34	23	19	12	75	116	113	6	14	37	114	40	27	18	648
		Using Semester System	34	24	19	9	71	93	88	10	14	47	94	32	20	16	571
		Using Quarterly System	12	9	6	5	23	25	27	8	4	13	22	11	8	3	175
Semester Statics First Started		Earliest*	1–2	2–1	2–1	1–2	1–2	1–2	1–2	2–1	2–1	2–1	1–2	2–1	1–2	2–2	1–2
		Latest*	3–1	3–1	3–2	3–2	4–1	3–1	3–1	4–1	3–1	3–2	3–1	3–1	3–1	3–1	4–1
		Most Frequent*	2–2	2–2	2–2	3–1	2–2	2–2	2–2	2–2	3–1	2–2	2–2	2–2	3–1	3–1	2–2
Semester Hours Scheduled before Starting Statics	Calculus	No. Curricula and Least Hours†	1 2⅔	1 2⅔	5 3	1 0	4 0	10 0	11 0	2 3½	1 3	5 0	11 0	3 0	1 0	2 0	48 0
		No. Curricula and Most Hours†	1 14	2 10	1 10	1 13⅓	1 16	1 14	1 14	1 13½	1 13	1 13½	1 14	1 13⅔	1 13⅓	1 13½	3 14
		Average Hours	5.43	5.82	5.48	6.67	6.46	4.94	5.32	6.81	6.59	5.20	4.99	5.89	6.26	5.64	5.54
		No. Curricula with Average or More Hours	24	14	9	6	43	54	50	8	12	24	56	21	15	10	308
	Physics	No. Curricula and Least Hours†	1 2⅔	1 2⅔	1 0	1 3	4 0	16 0	15 0	1 0	1 3½	6 0	18 0	3 0	1 0	1 0	66 0
		No. Curricula and Most Hours†	1 15½	1 15½	5 10	2 12	1 16	1 15½	1 15½	1 15½	1 12	1 15½	1 14	4 12	3 12	1 12	1 16
		Average Hours	6.35	6.85	6.27	7.85	6.83	5.41	5.85	6.69	8.08	5.78	5.12	6.62	7.57	7.00	6.12
		No. Curricula with Average or More Hours	18	21	10	9	41	47	55	7	9	24	50	24	15	11	272

* The first number indicates the year offered, the second number the semester; Example 2–1, second year first semester.
† The numbers in upper left corner indicate the number of curricula, those in the lower right corner the number of hours; Example 2/10 two curricula of 10 hours each.

	No. Curricula with Average or More Hours	18	21	10	9	41	47	55	7	9	24	50	24	15	11	272

* The first number indicates the year offered, the second number the semester; Example 2–1, second year first semester.
† The numbers in upper left corner indicate the number of curricula, those in the lower right corner the number of hours; Example 2/10 two curricula of 10 hours each.

TABLE I—*Continued*

122 Schools Included		Aeronautical	Agricultural	Architectural	Ceramic	Chemical	Civil	Electrical	Physics	Geological	Industrial	Mechanical	Metallurgical	Mining	Petroleum	Total All Curricula
Statics	No. Curricula Requiring	46	32	25	14	94	118	115	18	18	60	116	43	28	19	746
	No. Curricula and Least Hours†	9 2	7 2	9 2	1 1½	1 1½	2 1½	1 1½	1 1½	1 1½	1 1½	1 1½	1 1½	1 1½	1 1½	4 1½
	No. Curricula and Most Hours†	1 5	3 3½	1 4	1 4	3 4	1 5	1 5	3 3½	1 4	1 4	1 5	3 4	1 4	1 4	4 5
	Average Hours	2.85	2.73	2.64	2.69	2.57	2.84	2.74	2.64	2.52	2.73	2.82	2.76	2.68	2.40	2.73
	No. Curricula with Average or More Hours	29	19	16	9	56	80	68	12	8	40	75	26	17	13	450
Dynamics	No. Curricula Requiring	46	29	13	7	45	115	114	14	12	57	116	31	24	15	638
	No. Curricula and Least Hours†	13 2	10 2	5 2	4 2	1 1	2 1½	1 1½	1 1½	1 1	1 1½	1 1½	1 1	1 1½	1 1½	3 1
	No. Curricula and Most Hours†	1 5	1 3½	1 3½	2 3	1 3½	1 5	1 5	1 3½	2 3	4 3½	1 5	15 3	9 3	7 3	4 5
	Average Hours	2.78	2.57	2.54	2.29	2.29	2.77	2.72	2.54	2.06	2.67	2.80	2.47	2.44	2.44	2.65
	No. Curricula with Average or More Hours	29	15	8	3	21	75	70	7	2	37	78	17	12	7	381
Statics and Dynamics in One Semester	No. Curricula Requiring	6	7	4	1	17	11	16	2	6	7	14	7	6	5	109
	No. Curricula and Least Hours†	3 4	3 4	4 4	1 4	5 3	2 3	3 3	1 3	1 3½	4 4	1 3	1 3½	1 3½	1 3½	10 3
	No. Curricula and Most Hours†	3 5	4 5	4 4	1 4	2 5	4 5	5 5	1 4	5 4	3 5	7 5	2 5	2 5	4 4	32 5
	Average Hours	4.50	4.43	4.00	4.00	3.78	4.18	4.12	3.50	3.89	4.42	4.43	4.19	4.22	3.87	4.14
	No. Curricula with Average or More Hours	3	3	4	1	11	4	5	1	5	3	7	2	2	4	55

† The numbers in upper left corner indicate the number of curricula, those in the lower right corner the number of hours; Example 2/10 two curricula of 10 hours each.

TABLE I—*Continued*

122 Schools Included		Aeronautical	Agricultural	Architectural	Ceramic	Chemical	Civil	Electrical	Physics	Geological	Industrial	Mechanical	Metallurgical	Mining	Petroleum	Total All Curricula
Strength of Materials	No. Curricula Requiring	46	32	25	14	93	118	113	13	17	59	116	42	28	18	734
	No. Curricula and Least Hours†	2 / 2	1 / 2	2 / 2	3 / 2	12 / 2	1 / 2	9 / 2	1 / 2	5 / 2	4 / 2	2 / 2	7 / 2	4 / 2	1 / 2	52 / 2
	No. Curricula and Most Hours†	3 / 6	1 / 6	1 / 6	1 / 4	2 / 5	2 / 7	2 / 6	1 / 5	4 / 4	1 / 6½	9 / 6	1 / 4⅔	8 / 4	4 / 4	2 / 7
	Average Hours	3.80	3.45	3.49	2.93	3.12	3.99	3.27	3.25	3.06	3.51	3.81	3.12	3.17	3.17	3.49
	No. Curricula with Average or More Hours	24	12	11	11	27	71	41	5	5	28	61	17	11	5	284
	No. Curricula Having Lab. with Course	6	4	0	0	9	23	20	3	4	9	20	7	5	3	113
	No. Curricula with Separate Lab. Course	31	20	22	9	24	107	51	5	2	33	88	23	13	8	436
Fluid Mechanics	No. Curricula Requiring	32	28	3	0	3	118	74	4	16	31	110	9	22	17	467
	No. Curricula and Least Hours†	5 / 2	3 / 2⅔	1 / 2	– / –	3 / 3	4 / 2	2 / 1½	1 / 2	5 / 2	1 / 1½	6 / 2	2 / 2	6 / 2	3 / 2	3 / 1½
	No. Curricula and Most Hours†	1 / 6⅔	1 / 4⅔	1 / 4⅔	– / –	3 / 3	2 / 6	1 / 6	3 / 3	1 / 4	6 / 4	2 / 6	1 / 4	4 / 4	4 / 4	1 / 6⅔
	Average Hours	3.29	3.43	3.22	—	3.00	3.71	3.00	2.75	2.61	2.92	3.53	2.89	2.94	3.06	3.33
	No. Curricula with Average or More Hours	9	16	1	—	3	59	53	0	11	20	53	6	16	6	205
	No. Curricula Having Lab. with Course	11	21	1	—	—	87	30	0	4	12	58	3	8	5	240

† The numbers in upper left corner indicate the number of curricula, those in the lower right corner the number of hours; Example 2/10 two curricula of 10 hours each.

† The numbers in upper left corner indicate the number of curricula, those in the lower right corner the number of hours; Example 2/10 two curricula of 10 hours each.

TABLE I—*Continued*

122 Schools Included		Aeronautical	Agricultural	Architectural	Ceramic	Chemical	Civil	Electrical	Physics	Geological	Industrial	Mechanical	Metallurgical	Mining	Petroleum	Total All Curricula
Total Semester Hours Scheduled	No. Curricula and Least Hours†	2 8	1 7½	1 5	1 4	1 3	1 10	4 6	1 2	1 5	1 4	2 9	1 5	1 5	1 3	1 2
	No. Curricula and Most Hours†	1 22	1 17	1 16⅔	1 11	1 12	3 21	3 22	1 12	1 14	1 16½	3 22	1 14	1 14	2 14	4 22
	Average Hours	12.53	12.41	9.33	7.69	7.23	14.56	11.27	7.89	9.46	11.01	13.92	8.97	10.61	10.75	11.37
	No. Curricula with Average or More Hours	24	18	10	5	37	63	57	9	9	31	64	26	13	12	378
Per Cent of Total Hours Required for Graduation	No. Curricula and Least Per Cent†	1 4.51	1 4.72	1 2.98	1 1.96	1 2.14	1 5.86	1 4.14	1 1.35	1 3.40	1 2.80	1 5.59	1 3.27	1 3.40	1 2.07	1 1.35
	No. Curricula and Most Per Cent†	1 17.19	1 12.50	1 11.57	1 7.33	1 8.33	1 16.41	1 17.19	1 8.45	1 9.46	1 10.68	1 17.19	1 11.11	1 9.44	1 10.00	3 17.19
	Average Per Cent	8.64	8.52	6.13	4.56	4.91	10.02	7.62	5.30	6.27	7.50	9.45	6.15	7.11	7.25	7.73
	No. Curricula with Average or More Per Cent	21	15	14	7	41	55	60	11	9	29	54	19	11	12	399

† The numbers in upper left corner indicate the number of curricula, those in the lower right corner the number of hours; Example 2/10 two curricula of 10 hours each.

instruction and the emphasis placed on various topics under a particular subject. Also, the exact amount of material covered in each course was difficult to determine from the brief descriptions given in the catalogs. However, certain additional information was available on the general requests for these subjects among the various curricula of the same school, and the relative type of course in demand.

Intensity of Courses

Table II has been assembled to indicate the relative intensity of mechanics courses in each curriculum. The following criteria were used for classifying the data. When "type" is referred to in the following explanation, the kind, intensity, or quality of course is in question.

1. When only one type of the same subject is offered by the school, it is classified as the strongest.
2. When more than one type of the same subject is offered by the school and all requires the same amount of time, each is considered to be as strong as the other.
3. When more than one type of the same subject is offered by the school and one type requires more or longer instruction, that type is considered the strongest, and the other types are tabulated as condensed courses.
4. This table also indicates the number of schools that do not require

TABLE II

SUMMARY OF RELATIVE INTENSITY OF MECHANICS COURSES IN EACH CURRICULA

Curricula	Statics			Dynamics			Strength of Materials			Materials Testing			Fluid Mechanics		
	Strongest	Condensed	Not Required	Strongest	Condensed	Not Required	Strongest	Condensed	Not Required	Strongest	Condensed	Not Required	Strongest	Condensed	Not Required
Aeronautical Engineering	42	4	0	43	3	0	42	4	0	33	3	10	21	12	13
Agricultural Engineering	24	8	0	21	8	3	23	9	0	17	5	10	24	3	5
Architectural Engineering	24	1	0	12	1	12	22	3	0	20	2	3	3	0	22
Ceramic Engineering	10	4	0	5	3	6	7	7	0	8	2	4	0	0	12
Chemical Engineering	73	21	0	28	19	47	50	42	2	22	8	64	2	2	90
Civil Engineering	114	4	0	108	7	3	116	2	0	118	0	0	117	1	0
Electrical Engineering	98	17	0	100	15	0	75	38	2	51	14	50	43	33	39
Physics	16	2	0	12	2	4	8	6	4	6	1	11	3	1	14
Geological Engineering	14	4	0	7	5	6	9	9	0	4	0	14	12	4	2
Industrial Engineering	53	7	0	49	8	3	42	17	1	34	4	22	18	15	27
Mechanical Engineering	108	8	0	110	6	0	104	12	0	91	9	16	87	23	6
Metallurgical Engineering	33	10	0	20	10	13	20	22	1	23	2	15	6	3	34
Mining Engineering	23	5	0	17	6	5	15	13	0	13	2	13	17	6	5
Petroleum Engineering	17	2	0	13	2	4	12	6	1	10	1	8	13	4	2

some of the mechanics courses in the respective curricula.

Numerous schools, both with large and small student enrollments, offer only one type of some subjects, and some even offer only one type of each mechanics course. Other schools offer varied types of courses for each subject.

Distribution of Courses

Table III has been assembled to indicate the distribution of mechanics courses in schools and curricula. Using dynamics as an illustration, this table shows:

a. 492 curricula have the strongest course.

b. 55 curricula offer statics and dynamics in one course, and no other courses include these subjects.

c. 59 curricula offer statics and dynamics in one course, in addition to stronger courses offered for these subjects.

d. 31 curricula offer a condensed or shorter course.

e. 109 curricula do not require dynamics.

f. 85 schools have one type of dynamics course; 32 schools have two types of dynamics courses.

g. 415 curricula have one type of dynamics course; 181 curricula have two types of dynamics courses.

TABLE III

SUMMARY OF THE DISTRIBUTION OF MECHANICS COURSES IN SCHOOLS AND CURRICULA BY SUBJECTS

Subject	Number of Curricula Having							Schools Having				Curricula Having			
	Strongest Course	Statics and Dynamics in One Course		Shorter or Condensed Course	Course Not Required	Total	Requiring Laboratory	1	2	3	4	1	2	3	4
		Only	Also					Type Courses in				Type Courses in			
Statics	599	55	59	33	—	746	—	90	28	4	—	538	170	38	—
Dynamics	492	55	59	31	109	746	—	85	32	4	1	415	181	35	6
Strength of Materials	538			193	15	746	103	67	55	—	—	377	354	—	—
Materials Testing	378			50	318	746	428	82	25	—	1	314	107	—	7
Fluid Mechanics	396			76	274	746	237	74	39	8	—	274	161	37	—

HUMAN RELATIONS IN THE ENGINEERING CURRICULUM

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We hear much these days about the pros and cons of "human relations training in industry" and as to "how our evolving technology is impelling the engineer, whether he wants to or not, to go in the direction of having to assume an executive role in American industry." If it is so vital to engineering-executive development, where can human relations training find a place in the undergraduate picture?

Those of us teaching non-technical subjects in engineering are faced with the problem of designing courses best suited to the needs of the engineer. In this article we wish to describe a basic psychology course, with emphasis on human relations, designed specifically to fit within the humanistic-social stem of the engineering curriculum at the Carnegie Institute of Technology.

Why a course in psychology for engineers? There are two cogent reasons. First, a majority of the graduates of engineering schools find themselves in positions of an administrative, supervisory, or executive character within a few years after graduation. There is no reason to expect any change on this score. Indeed, most engineering students do not want a change, if for no other reason than the fact that financial remuneration is highest among positions of this nature. Second, business and industry have to date been unable to solve many of their personnel problems. Apparently the psychological know-how necessary is at present lacking or at least is not being put into practice. Since many of the most pressing problems confronting the supervisor, administrator, and executive involve personnel relations, it is reasonable to equip the student in training for such jobs with all the psychological tools that will aid in the understanding of human relations situations.

How best a course in psychology for engineers? Proceeding on the assumption that engineers need a separate course in psychology, the problem might appear to be solved by simply requiring all students to take such a course sometime during their training. The solution is not so simple in view of the experience at Carnegie with the conventional psychology course. By "conventional" is meant the use of a standard psychology text and the presentation of illustrative and explanatory material through lectures and experimental demonstrations by the instructor.

This so-called conventional method, with its emphasis upon textbook content, has proven somewhat sterile. The typical engineering student shows little evidence of being able to adapt his textbook psychology to realistic problems of the type he will encounter in professional life. He does well enough on objective content

examinations and pays lip service to scientific psychology. When required to analyze a human relations problem and formulate a sound solution, however, it never occurs to him that his psychology has any relation, or else he states that an answer is impossible until an experiment can be conducted.

One student remarked that industry should cease operation for two years so that psychologists might conduct enough experiments to settle industry's human relations problems scientifically. A good point theoretically perhaps, but not a very practical one; and even then, the problem would still be one of using psychological findings as an *aid* to judgment, not as a substitute for it. In short, what the student fails to acquire from conventional courses is an interest in and ability to use psychological aids.

It has been suggested, therefore, that engineering students, and indeed all non-psychology majors, be taught a course in applied psychology instead of the regular introductory course. This does not appear to be a very satisfactory approach either. Leaping directly into applied psychology seems to create the impression that psychology is just a system of tricks, some clever scheme for getting people to do what they ordinarily do not want to do. Students feel that they are in a position to "use" psychology in the sense that the high pressure salesman and unscrupulous politician "uses" it, failing to appreciate that such persons no more "use" psychology than the boy who kicks a football "uses" physics. These observations point to the conclusion that what is needed is not a course in applied psychology, but instead a course in *appliable* psychology.

In an attempt to resolve the difficulties of both conventional and applied approaches, we have developed a three-credit, one-semester introductory course entitled "The Psychology of Human Relations." This course is taken during the junior year and is required of all engineering students. It stresses the *induction* of fundamental principles by the student, plus practice in the systematic application of these principles to a wide variety of human relations. The basic principles are carefully selected beforehand by the instructor, but are not presented to the student. Instead, the student is encouraged to induce these fundamentals from instances of human behavior that are comprehensible to him because of his previous experience. The student—not the instructor—is required to make the generalizations. Checking the hypotheses through deduction is the final stage in building up a set of basic principles for later use.

An example of the instance-induction procedure can be taken from the field of motivation. The student is asked why men work—or why men eat—or why certain people go to school—or why people rationalize. These questions generally yield workable answers which are couched in terms of the satisfaction of some want, need, or desire. The student quite readily generalizes that motives are the reasons for behaving and that these motives are varied and complex. With this background, and some opportunity to apply the generalization in specific situations, the student is in a position to see, among other things, the futility of dealing with all human behavior in terms of financial or monetary incentives.

Concurrent with the development of psychological principles, the student

is introduced to concrete human relations problems of varying complexity. These may deal with adjustments at home, in school, or in industry. Every attempt is made to use previously-derived principles in new and concrete cases. Apart from the induction of basic principles from instances, the solving of concrete problems by the student is the chief class activity. The problems are selected so that the student sees the necessity for first carefully determining the real problem at hand, and then planning his proposed course of action.

How effective has the course been in accomplishing its aims? As any teacher knows, it is most difficult to evaluate the effectiveness of teaching at the behavioral level as well as the verbal level. However, we do have some evidence that the methods used in the course, "Psychology of Human Relations," is the best approach yet tried at Carnegie in teaching a one-semester unit for engineering students. We believe the main goals of the course are being realized. Many Carnegie students take advanced elective courses in social psychology, industrial psychology, and the psychology of adjustment. Although these students do not have at hand a wide range of factual material from the basic psychology course, they do appear to have an appreciation of fundamental principles in the areas of emotion, motivation, learning, and adjustment.

This is indicated by the way in which they are able to handle realistic problems in the advanced undergraduate courses, by their analyses of the uses and limitations of psychological procedures and by the realization that many concepts developed under experimental conditions have application in real life situations.

On the more objective side, experimentally controlled studies have been made before and after the course to determine student attitudes toward dealing with human problems. Significant favorable gains were evidenced from those students having taken the course in comparison with control groups who had not.

There is another type of evidence that the course has been "sold" which we believe to be of some importance —the engineering faculty feels the course is meeting a vital need of their students. Whether this attitude is due to the effectiveness of the course, or to the participation of key engineering faculty members in helping establish the course, or to both, is unimportant. It has given us a favorable environment in which to work.

Over the past seven years in which the course has been evolving, the Provost and Deans concerned have made available opportunities for the psychology staff and engineering faculty to work closely together on various educational problems. The engineering faculty visits our classes in psychology and we visit some of those in engineering. We exchange ideas on teaching methodology. Let no one overlook the advantages of this kind of immediate human relations in teaching psychology to another professional group!

ON TEACHING DESIGN

With Special Application to Civil Engineering

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A paper presented at the meeting of the North Midwest Section, ASEE, held at South Dakota State College, Brookings, November 4–5, 1955

The traditional civil engineering course has long been criticized because it does not produce enough graduates capable of doing design work. Few are trusted with responsibility for design until they have had years of experience, and even then not until they have been cautiously tested on minor projects or on those where the opportunity exists for a careful review of their work. Many fall by the wayside.

A common opinion is that one is born with design sense or is not, and that the years of sub-professional practice are not so much for education as for discovering and winnowing out those unsuited for this type of work. An employer of young graduates who hopes to obtain designers first tests them on routine computations, drafting, and analysis. These are basic skills all graduates are supposed to have acquired in school, and indeed most of them have.

When opportunity presents, the young graduate who has proved himself able to do the routine work satisfactorily is given some real design work to do, and his product is carefully weighed. He is seldom allowed many failures. In spite of the fact that considerable attention is given to "design" in the civil engineering curriculum, it is at precisely this point that too many of our graduates reach their limit.

I believe that this is true because we engineering educators have not, in the main, understood what sort of teaching procedure is necessary to train designers, and except in rare instances have not been giving our students the type of training they really need. We have thought of design as being the particular sequence of computations one goes through in order to proportion structural members so that they will conform with the specifications or building code. In the standard textbooks, the treatment of design problems is limited almost entirely to details of typical structures, methods of analysis, special computational procedures for determining sizes, and codes or specifications. Now I do not say that this knowledge is useless. I merely say that such study *per se* is not effective in producing designers.

In order to determine how students should be trained to become designers,

let us consider what the successful designer does. He must:

(1) foresee every final demand that a given structure will be required to meet.
(2) be able to conceive, in fairly complete detail, alternative plans that will meet the requirements economically.
(3) determine which plan is most satisfactory and economical.
(4) be able to complete and set down the finally selected plan clearly enough so that the draftsman can draw it and the contractor can build it.

Our present teaching methods give some training to develop the student's ability in communicating his ideas, and in analytical methods. The latter are necessary aids to the judgment in selecting the most feasible plan, but they give practically no opportunity to develop the abilities needed for the first step of the designer's work, and little real practice in developing the kind of judgment designers need for the third step. Even the best of our graduates are likely to overlook some minor but important function of the structure, or to prepare only one design and defend it stubbornly against suggested alternatives.

There is a way of teaching design, however, that *does* foster real development along all these lines. It benefits the students who have a natural inclination towards design much more than does the old type of instruction. Instead of starting by teaching the use of the specialized tools in the designer's workbag, the new method plunges directly into problems which involve the whole range of design activity. Problems are simple at first. As they become more complex, the use of any specialized tools which may seem to be needed is explained by the instructor.

The student may first be asked to design a garage, one for his own use that he may wish to build after he graduates and settles down in a new home. The result asked for is a set of plans and specifications that would tell a carpenter foreman what is desired. When his design is completed, each student presents it orally to the other members of the class, who are encouraged to ask questions and to criticize as a board of review. Often questions are asked that show up serious defects. If not, the instructor should bring them out tactfully by such questions as "Are you sure the beam over the double door is strong enough, and won't deflect too far?"

The question and answer period is important, and it calls for the greatest skill on the part of the instructor to create the right psychological atmosphere for free class discussion. Amazing individual differences come to light, with some of those who evidence good design sense showing serious defects in the way of too little or too much self-confidence. By the end of the course, though, those who have real design talent will know how to defend their ideas. They have learned to compromise judiciously and quickly when a valid criticism is made.

By the end of the course, too, those who have little talent for design will be thoroughly convinced that they should seek some other type of work. Under the traditional type of instruction, these same individuals might be in a far worse position. If they were able to follow successfully the typical designs worked out in the textbook, they might have earned a high grade

in the course and a false idea of their ability as designers, an idea that might easily doom them to many years of frustration. In, on the other hand, they received a low grade, they might or might not be convinced that they could not design. It should also be pointed out that in the traditional type of course, some students who receive a low grade might even have considerable design talent. This is especially true when in his grading the instructor puts too much emphasis on superficial aspects of assignments.

In the new type of course no text is used, but a great deal of thought is given to the selection of suitable problems graduated in difficulty, and short enough to permit fairly complete study. In view of the growing importance of other types of civil engineering work, it would seem desirable to broaden the scope beyond the customary structural projects. The exercises should be short, and the student should be allowed time to do his own thinking. In starting a new course of this type for seniors, the staff of the whole civil engineering department should cooperate in finding and selecting suitable problems.

The writer has used this method of teaching design for courses in both steel and hydraulic structures. Special courses under structural and sanitary engineering instructors have also been given to small groups of graduate students in the department. In steel, the problems have been mainly structural, progressing from the simple garage discussed above to industrial buildings and bridges. In the other courses, problems requiring a wider range of basic knowledge have been used. One good example is the design of a pump house; this involves hydraulics, soil mechanics, and structures. A temporary weir to be built in a storm sewer provided good hydraulic and structural practice and developed a good appreciation of the necessity of considering the method of construction.

On some of the problems, a complete range of the more obvious designs was prepared every year, yet hardly a year passed without some novel design appearing. The best design so far obtained on one problem was produced by a student who, despite rather mediocre computational ability, became a designer of recognized standing within a few years after leaving the classroom.

Students in design courses should always be given a little instruction to prepare them for the task of "checking." There are two possible guiding philosophies for the "checker." When the contrast is brought to their attention, they can select the one that is more likely to lead to success, and are less likely to follow the other without thinking. One is "Never leave any feature of the design the way it is if you can think of any possible reason for changing it," and the other "Never make a change in the existing design unless it is absolutely imperative."

The dangers of "checking" designs by verification of the detailed computations should be pointed out and the students trained to check from completed plans, starting with the most important general features and following through to the details. A most satisfactory examination can be given by asking the class to check plans that embody several defects; these, of course, should vary in conspicuousness and importance.

Many skillful teachers have known the methods described herein and have used them, usually in the courses in steel and masonry which almost

always have enough computation periods to give time for practice. Unfortunately, however, many have not. Even where good methods of teaching design have been used, the methods have too often been solely structural. There is no reason why the student's background in other fundamental subjects should not be drawn upon. The philosophy is, of course, the same as that underlying the "case method" or "project method" used in other fields of engineering.

Many employers say that they would rather have young graduates well trained in fundamentals than in particular applications. What they mean, of course, is men able to apply their knowledge of fundamentals to new problems. This demands creative or problem-solving *practice*, not merely a more nearly perfect or more extensive memory of the fundamentals. We should act now to insure that at least a small part of the student's training will be this kind of practice, and not all of it the sort of instruction that is in reality a conducted tour through interesting applications devised by others.

CORNELL SCHEDULES ELECTRON MICROSCOPE COURSE

"Techniques and Applications of the Electron Microscope," a summer laboratory course intended to offer an intensive survey of basic theory and data interpretation, will be given from June 11 to June 23 by Cornell University's Department of Engineering Physics. Under the direction of Professor Benjamin M. Siegel, the course will have as guest lecturers Cecil E. Hall of the Massachusetts Institute of Technology and Robley C. Williams of the University of California at Berkeley.

Registration is limited, so that ample facilities will be available for each member of the group to pursue laboratory work in his special field at an introductory or advanced level, depending on previous experience. Inquiries should be addressed to Professor Siegel, Rockefeller Hall, Cornell University, Ithaca, New York.

ANOTHER LOOK AT GENERAL STUDIES

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President Jess H. Davis's reflections on "General Studies for Engineers" ought not to go unchallenged, though one cannot help feeling that to "reply" to President Davis's article in the October issue of the JOURNAL (p. 109) is to take unfair advantage of the willing speaker who plays (as I think he does) the devil's advocate for the purpose of encouraging discussion. President Davis's words have an eager and a nipping air about them which is bracing, and his forthright manner does not want for sincerity. Therefore, so as not to appear unsportsmanlike, I should say that I respond to President Davis in the same spirit of impromptu "give and take" that he shows in his paper.

At the outset, I feel at a slight disadvantage. President Davis's animadversions tend to put one in the position of defending "Culture for Engineers," which I cannot do. Like him, too, I am at a loss to know *for sure* what culture means in this context. Or, if it means what I suspect it means, then one must confess that he would scarcely wish to waste his time defending so provincial a notion. Moreover, I know of no *teacher* of the humanities today who would be so absurdly old hat as to subscribe to, let alone preach, the idea that humanistic learning is intended (for engineers or for anyone else) as something *ornamental*, to be displayed only on ceremonial occasions.

Indeed, that is the first and most important point I have to make (and it is, I believe, central to the issue). Humanistic learning is a discipline in its own right, ancient and honorable, with a vast body of knowledge from which to draw. It has its own ancient, honorable, and effective methods of inquiry, with a vigorous pride in the inexhaustible riches it is heir to. It has its own profound and determined desire to preserve the best, with its own highly disciplined scholarship, with its own logic (just as severe in its way as the logic of science), its own ideals of perfection, its own dedicated minds.

One might as well let the cat out of the bag at once. Humanistic learning is not adjunct to any other body of knowledge or methods of inquiry. If one wished so to construe their place in engineering education, one might say that the humanities are interlopers; but no one could accuse the humanities of being Johnny-come-latelies in the noble society of learning.

President Davis shares with many other administrators the notion that the humanistic-social stem in engineering education is auxiliary to the science of engineering. No one now would think of denying chemistry or physics or mathematics an autonomous place in the liberal arts college; why

should one venture to suppose that the humanities should be service appendages to chemistry or physics or engineering mechanics in an engineering college?

Though President Davis does not insist that the "results" of humanistic study must be capable of quantitative measurement, still he is uneasy because he cannot (both as administrator and as engineer) determine how close "we" come to meeting the objectives of the humanistic-social stem in engineering education. The general objectives of the humanistic-social stem, as stated in the 1945 Report of the Committee on Engineering Education After the War, are, President Davis finds, presented in words both indefinable and perplexing. Of course they are—from the strictly engineering point of view. Considerable credit should be given the members of the Committee for the daring they showed in mapping out a direction without benefit of slide rule.

Still greater credit should go to those members of the recent Committee on Evaluation of Engineering Education for the broad and forceful stand they have taken in re-affirming the earlier ideals and directives. One must remember that these committees were not writing systematic philosophies of education, but were taking upon themselves the roles of explorers trying to establish a line of march.

Humanistic-social aims cannot be expressed algebraically or trigonometrically. They were never intended to be subject to the kind of universal agreement which numbers so easily command, and they never will be. But they are responsive to another kind of measurement—the human in its fullest sense, that is, in terms of wholly human values. And the achievement of human values cannot be accomplished all of a sudden, say in four college years. It may well take three score and ten years before the candidate is ready to be examined in his humane learning.

What enlightened board of trustees ever had the temerity to say that the student must have accumulated a measurable quantity of humanistic understanding—intellectual courage, tolerance, aesthetic awareness, emotional maturity, creative sensibility, compassion—by the end of his senior year? If one thirsts for more concrete terms with which to talk about the objectives of the humanities, it will be no refreshment to turn to the physical sciences for a loan of their language. One has rather to draw more deeply from the well of the humanities themselves. There is meaning in the term "human values," though as with a differential equation, the meaning may not readily be grasped until one has given the prerequisite studies considerable attention. A mark of engineering science is that it can be mastered, after a fashion, in four or five years of undergraduate study; it is equally a mark of humanistic learning that only a rare soul ever masters it, even after a fashion.

As all teachers of the humanities know, humane learning often has to deal with subtleties that defy systematic analysis and formulistic presentation. In the arts particularly, discursive reason may be the least rewarding approach to their understanding and enjoyment. Indeed, the enduring strength of a piece of literature may lie in its "non-rational" manipulation of symbols, its ambiguities and ambivalences, which have to

be surprised by insights and intuitions if they are to be captured at all. I am reminded here of a verse by Marianne Moore entitled "Poetry," which opens with these lines:

> I, too, dislike it: there are things that are important beyond all this fiddle.
> Reading it, however, with a perfect contempt for it, one discovers in
> it after all, a place for the genuine.

Are not all the humanistic studies striving largely to find the genuine and bring it to light, wherever it may lie hidden, in science or the arts? If at times the humanistic approach to reality is quite different from the scientific approach, it is not for that reason dispensable. The competent humanities teacher finds himself in a position where he can appreciate and give credit to both points of view. Is it too much to ask that the engineer pay his respects to the humanistic approach, which, though often different from his, is in its field equally valid and successful?

Subject-Matter

When President Davis turns his attention to the subject-matter of humane learning, to the content of courses in literature and the fine arts, for example, he presses hard on the most sensitive area the teacher of the humanities has had to learn to live with—lack of motivation on the part of engineering students toward the humanistic studies. Of course President Davis is right when he says we must first capture the interest of the engineering student. His remarks in this connection are unarguable, and the humanities teacher breathes agreement with him.

That engineering students have a very high degree of motivation toward their engineering subjects and a low (though not so low as some would put it) degree of motivation in the humanities is a fact not better known to anyone (not even to a college president) than to the "plain" classroom teacher. But the teacher of humanities (or of the social sciences) in an engineering school is a confirmed optimist, and he tries unwearyingly every device known to Heaven and man to motivate student interest in the enduring works of the human mind and imagination. Engineering students have very lively minds, capable of reaching out in many directions enthusiastically—if encouraged.

To be sure, there is nothing wrong with beginning with the modern writers in a literature or in any other course. There is everything right with introducing students to literature by way of Bernard Shaw or Sinclair Lewis or Scott Fitzgerald or Dreiser or Hemingway. And the truth of the matter is that most freshman English courses in engineering schools make it a point to introduce the student to literature by way of the modern. But this is only the beginning. Where do we go from here? Somewhere, sometime, we are going to have to face Shakespeare and Dante. Give the good teacher time, and he will find a way. Only be sure that you do give him time.

As head of a Department of Humanities, I have found not so much that the great writers and thinkers are unteachable, but rather that they require a *good* teacher. And most colleges (engineering and other) are not willing to pay for good teachers, either in time or in money. What makes a good humanities teacher? Just this —as thorough a knowledge of his subject-matter as the engineer has of his,

and in addition an abundance of time —time to work with and for his students, time to think about what he is going to do, time to do it in, time to develop himself, and time for study and reflection.

To give a teacher time for his work means freeing him from heavy teaching assignments, from responsibility for large numbers of students, from busy-work, administration, from the casual and non-essential. It often seems that the teacher is expected to do just about everything *but* teach. He draws up syllabi which tell what he is going to do; he writes reports and fills out questionnaires which tell what he has done. I sometimes wonder when he really does what he says he does. Give the devoted teacher time, and he will find a way to interest engineering students in the mighty works of the past. And give the engineering students more time in which to prepare for their humanities subjects, and the curve of motivation will rise with astonishing speed.

Nor is the charge of superficiality which President Davis levels at humane learning in engineering schools quite merited. Depth of knowledge is a matter of degree, as President Davis must know. Since the aim of the humanities is the humanizing of the student (any student—engineering, medical, business administration, or liberal arts), it is perhaps not a question of subject matter to be consumed or even a problem in deepness of inquiry. In other words, it is not a matter of imparting a given quantity of concrete, objective, testable pieces of information, but rather a question of enriching the individual student's own personality, of broadening his outlook, of civilizing his attitudes. And given the small amount of time allotted the humanities and the social sciences in engineering schools, the wonder is that teachers of humanities do as well as they do.

President Davis is an old-school engineer. I am an old-school liberal arts man. I salute President Davis's thought that objective measurement is a worthy aim in the branches of human thought where it is applicable. I would like to feel that he is as ready to pay his respects to mathematically unmeasurable literary values, abstract philosophic thought, and to the complex of human values which is inevitably a part of the human condition. If the engineer will make allowances for the humanistic approach to experience, as the humanist makes allowances for the scientific approach to material reality, together they will make a distinguished pair. The result will be the new-school engineer-humanist who has the advantages of both points of view.

(The quotation from Marianne Moore, *Collected Poems*, 1951, is reprinted by permission of The Macmillan Company, N. Y.)

AIM FOR AMES IN JUNE!

A MATHEMATICS TEACHER LOOKS AT ENGINEERING COURSES

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There seems to be a growing tendency in our engineering colleges to center the teaching of advanced mathematics at least within the engineering college itself rather than to have the mathematics department do it. Obviously the engineers are dissatisfied in some sense or other with the work the mathematicians are doing. One reason frequently given is that there are already too many courses the student must take, and he does not have time for a separate mathematics course. Therefore it is not possible to require mathematics beyond the calculus, and additional mathematics can be taught in the engineering courses as the need arises.

This makes for such courses as electric circuit theory (as given in some schools), which turns out to be the equivalent of an advanced mathematics course, including solutions of polynomial and transcendental equations, some elementary differential equations, practical Fourier series, plus Fourier and Laplace transforms, with a smattering of Gamma and Bessel functions. Similarly, much time in a course on mechanical vibrations is spent acquiring information about the sine curve and its uses.

On the other hand, much of the mathematics a student has learned is not put to use. Consider the beam deflection problems in elementary strength of materials. Here it really does not matter whether the student can integrate such a function as $x^n\,dx$ or not. An entirely new method—that of moment-area diagram—is taught him. (We must admit, this method *is* quicker and much simpler, once you get the hang of it!) Or consider the problem from the advanced strength of materials text, in which the object was to show that a certain phenomenon gave rise to the equation of a straight line. Polar coordinates were used and the polar equation of the line was achieved without too much effort. But apparently a student sufficiently advanced to take such a course is not supposed to know about polar equations of lines, for the text gives in detail the mathematics necessary for change into the rectangular form before it dares state that the result is a straight line.

Again, there is a waste of time and duplication of effort between the engineering faculty and the mathematics faculty in teaching such things as moments or areas and volumes. It is not at all unusual for a student in integral calculus to come up after class when work on moments or volumes has been started and remark that he is doing the same thing in statics. Of course such duplication does not hurt the student, but in view of the fact that he has so much to cover, is it quite wise? (Duplication is not always the case, incidentally. The engineers'

fears are sometimes justified, as evidenced by the student who said he had just completed a course in integral calculus in which the teacher had not solved one practical problem!)

Just what, then, is the place of mathematics in the engineering curriculum? What should be taught? Who should teach it? How can these matters best be decided in a given situation? To settle the easiest question first, mathematics should definitely be taught by the mathematician, the one who is trained to teach it. If there is one on the engineering faculty trained in mathematics, there is no good reason to forbid his teaching the mathematics required if such seems to be desirable.

The term "being trained in mathematics" implies a person who could equally as well have obtained a position on a university mathematics faculty as his present engineering appointment. If this is not the case, it must be assumed that the members of the mathematics faculty are better trained and more qualified to teach the mathematics courses than are the engineers.

On the other hand, it is perfectly true that all mathematicians are not equally adapted to teaching engineering students. If possible, the student should be under someone who is familiar with the engineering curriculum. If the mathematics teacher is not acquainted with the curriculum, he should become acquainted with it. The engineering college should cooperate, but it can expect the mathematics teacher to take the initiative.

Psychologically it would be good if engineering classes, especially in elementary mathematics, could be set up for engineering students only and could meet in regular engineering classrooms. This would keep the instructor reminded of the fact that he was teaching mathematics primarily as a tool, and would give the freshman more of the feeling that the mathematics was actually a part of his engineering training rather than just another extraneous required subject.

This brings up the next question of what mathematics should be taught. If two people can be found to agree on this matter, I do not know where they are. [*Editorial Note:* Some advanced-subject progress is apparently being made on Miss Rohde's point, as the Report of the Pasadena Conference on Mathematics, page 585, may show.] Yet I feel definitely that certain topics should and could be omitted for the engineering student, with others emphasized more than they presently are.

There is no reason why the algebra, trigonometry, analytic geometry, and differential calculus needed cannot be covered in the first year of college if a little cooperation is established between the mathematics and engineering faculties. The engineers will have to take time to inform the mathematicians just what subjects or emphases are and are not needed for engineering practice. The mathematicians will then have to teach with these goals in mind, or convince the engineers that other methods would be better. Certainly all theory cannot be omitted, for, though mathematics is to be primarily a tool, a certain amount of "mathematical maturity" is necessary to undertake intelligent study of special topics, primarily those required for advanced degrees.

One of the criticisms of present mathematics courses, both elementary and advanced, is that there are not enough practical problems solved in

class or assigned for homework. Members of the engineering faculty could help here by taking an hour or two and writing out some practical problems that might be used in the mathematics courses. These could be filed by the mathematics group, and added to from year to year, making a good supply of problems available at all times. Such problems, incidentally, should realistically include extraneous information, so that the student would need do more than find a formula involving exactly the quantities given in the problem and then substitute. (One of the most harrowing experiences of my life was to be given a problem in strength of materials in which there was some information for which I could find no immediate use!)

Except for the rare two-year unified courses, the first mathematics most college freshmen encounter is algebra. Here several weeks are sometimes devoted to a review of high school work, even going back to what was done in the ninth grade.

For a student qualified to take the course in the first place (one with two years of high school algebra and sometimes more) nothing could be worse than this method of beginning the semester. He feels it is only a "rehash" of something he has already had; he gets by with little or no study; the pattern is set. He is not going to do any studying for the rest of the semester in that course. Such things as the solution of linear and quadratic equations, factoring, and handling of fractions can just as well be reviewed on the student's own as he finds necessary. This would be the scholarly way of doing things.

If we must start with something simple, a discussion of inequalities might well be in order. The student would feel he was learning something new and would begin a program of *study* rather than of neglect for his mathematics. The two or three weeks saved could be devoted to solutions of polynomial equations by numerical methods and other desired topics.

As for trigonometry, a thorough foundation in the measurement of angles, both by degrees and radians, in the trigonometric functions, and in the fundamental identities and their use would seem sufficient. Certainly these topics are needed, either immediately in engineering, or for the development of the so-called mathematical maturity mentioned earlier. Special attention should be given to the discussion and graphing of sine and cosine curves, with amplitude, phase, period, and frequency emphasized. The addition of ordinates in graphing linear combinations of such curves is also most useful. The development of the sine and cosine formulas and others for solving triangles is hardly necessary; possibly two or three days could be spent on their use.

This would be a good place for a discussion of significant figures and rounded numbers, a subject which is important to the engineer. Since there are so many different opinions about this subject, it would be well for the mathematics and engineering faculty to have a common method. Occasional practice in the engineering classes of carrying an irrational number in its exact form, such as π, $\sqrt{3}$, or $\log_{10} e$, to the end of a problem would not be amiss, either. After all, 2.828 may look like $2\sqrt{2}$, but it might represent almost anything else as well. Suppose you decide at the last minute you want five significant figures and are not sure about their validity?

Most of the time spent in analytic geometry on the conic sections (in other words, most of the time spent in analytic geometry, in many cases) would seem to be wasted on the engineering student. To paraphrase a verse of Scripture, "For what is a man advantaged, if he gain the equation of the directrix in the new coordinate system after the axes have been translated and rotated, and recognize not the equation of a straight line or a circle in polar coordinates?" To know that $5x^2 - 13xy + y^2 + 2x - 10 = 0$ is an hyperbola is enough without being able necessarily to put it in standard form.

Probably the greatest objection to the teaching of calculus is the failure to emphasize the use of integral tables. As we all know, much time could be saved for more important things if the student were allowed to use tables in integrating functions such as $(3x + 1)dx/(2x^2 + 5x + 8)$. Again, since the engineering courses cover thoroughly the subjects of moments, areas, volumes, and the like, possibly some of this work should be omitted in the calculus and the time devoted to other topics, say an introduction to differential equations.

In a course streamlined for engineers along such lines as have been suggested, I feel certain that the student could be given in three semesters as much *necessary* mathematics as he now gets in four. The fourth semester could then be devoted to a good course in differential equations which would include special emphasis on graphical and numerical methods, series solutions including Bessel functions, and boundary value theory with applications to specific problems in engineering. I have no proof for this statement, for I have never had the opportunity to try such a thing, although I would certainly like to do so.

With the exception of the differential equations, there is probably no single text which would be suitable for any one or two semesters of such a program. Of the so-called unified texts today, all are written for wider audiences than just the engineering student. Sometimes I think a student learns more without a text, anyway, when he has to pay attention and take notes. Certainly there would be plenty of reference material. Given a teacher interested in his work, the program should be a success for two reasons: first, the student would know he was getting something he could use later on; and second, he would have to work harder from the beginning and so would get into the habit of studying regularly.

Assuming subjects taught as outlined in the first two years, there should be little necessity for the engineering faculty to do more than a cursory review of any mathematical subject in their courses. The student who needs more mathematics will then be able to find time for advanced courses covering such topics as vector analysis, partial differential equations, complex variables, matrix theory, Boolean algebra, and so on. Vector analysis and partial differential equations with some applications can be covered in a three-semester-hour course, as can the complex variable theory needed for the more elementary applications. These are probably the subjects most often required. By the time a student has got through this much mathematics, he is usually mature enough to learn for himself by reading what he needs of other topics, given appropriate references.

Finally, to aid in the success of any

such program, there must be direct exchange of ideas between engineering and mathematics instructors. When an engineering instructor finds that a particular mathematics course, especially one which has been designed for the engineering student, contains more theory than he thinks it should or omits something he thinks should be included, let him tell the mathematics faculty about it *in person*. He must remember that the mathematician teaching the course will probably be only too glad to get suggestions, but that the students do not always pass on everything that is told to them. A joint effort by mathematics and engineering staffs, however, will go a long way toward advancing the efficiency and usefulness of mathematics instruction as a part of engineering curricula.

"JETS" HIGH SCHOOL PROGRAM

Junior Engineering Training for Schools (JETS), a science-club plan originated in 1950 by Lorin G. Miller, former Dean of Engineering at Michigan State University, now includes 75 clubs in eighteen states, with an active membership of more than 2,000 high school boys and girls. The JETS program is intended to do for engineering what 4-H and FFA have long been doing for agriculture.

The JETS clubs get first-hand information from a variety of sources. Projects are recommended, conferences and talks are scheduled by college staff members or industrial engineers, films and publications are obtained for study and review. To help clubs get started, JETS headquarters has supplied lists of suitable projects, and an index of more than 100 motion pictures available without charge from industry and other organizations. Added incentives for members of JETS are provided by judging recognition of club projects and by scholarship awards to the outstanding member in each club.

Success of the JETS program has already brought requests for information from more than 60 engineering colleges, societies, and industries. The JETS idea has been developed as a national secondary-school pattern which can be utilized freely by engineering colleges everywhere. Director Harold P. Skamser, School of Engineering, Michigan State University, East Lansing, offers assistance to ASEE institutions and industries in adapting the basic JETS plan to the special needs of their own areas.

SENTENCE AND WORD LENGTH IN SCIENTIFIC WRITING

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Scientific writers are frequently urged, rather arbitrarily, to shorten their sentences and words. Too often it seems that those who would change the scientific writer's style in these respects do not fully appreciate the special problems of the field. In scientific and technical writing, sentences frequently must be long in order to express essential qualifications and reservations, and short equivalents for polysyllabic terms often do not exist.

Perhaps the attention that the various systems for measuring readability have received in recent years is responsible for a general feeling that all writers should shorten their sentences and words. These readability measuring systems are based on sentence and word length; quite simply, the longer a writer's sentences and words, the lower will be his readability rating. One would question the validity of such crude measuring systems. Although it is true that sentences containing non-associated ideas are low in readability, all long sentences do not err in this respect; and although polysyllabic words may, in general, be less familiar than their shorter equivalents, this is not always the case. Moreover, as has been observed, in scientific and technical writing polysyllabic terms are unavoidable.

Readability means nothing more than reading ease, and scientific writing should certainly be easy to read whenever possible. However, in this type of writing, reading ease does not necessarily result from simplicity of expression. For exposition, completeness and precision are essential; if these qualities cannot be obtained by the use of short sentences and short words, long sentences and long words must be used. An attempt to convey a sophisticated concept in short sentences and short words could easily be less readable than a more complex, and hence more appropriate, expression. It may well be that the reader of scientific and technical material, accustomed to devoting a measure of attention and concentration to his reading, feels that *necessarily* long sentences and words are quite readable.

Scientific vs. Popular

In fact, the readability measuring formulas proposed by Flesch and his followers for popular writing fail to distinguish between sentences and words that are necessarily long and those that could be shorter without loss. This failure to distinguish levels of communication responsibility suggests that these systems may be misleading if applied to practical writing.

So much for theory. It now remains for this theory to be tested. The purpose of this paper is to report the results of an effort to determine the correlation, if any, between the length of sentences and words in scientific writing and the readability of that writing, as judged by those who normally read it.

Test Evaluation

Representative samples were drawn from 17 reports in the field of science (one sample from each report) and were rated by means of the readability rating system developed by Rudolf Flesch.[1] In this system the average number of words per sentence and the average number of syllables per 100 words are computed; then, by means of a formula[2] developed by Flesch, these averages are expressed in terms of a Reading Ease Score. This score ranges from 0 to 100; the shorter a writer's sentences and words, the higher is his score. By this token, the higher his score, the better writer he is. (A comic book, for example, in which half the words are of one syllable and the other half are two syllables, and in which all the sentences are five words long, would have a Reading Ease Score slightly under 75. A perfect score, of course, can be obtained only by mono-syllabic one-word sentences; random nonsense would qualify beautifully.)

The Flesch Reading Ease Scores for the 17 samples of scientific writing ranged from 23.4 to 45.3. The mean for the samples was 29.4. Six of these 17 samples were used in the test: the two with the highest Reading Ease Scores (45.3 and 36.2), the two with the scores closest to the mean (28.8 and 26.4), and the two with the lowest scores (both 23.4). These six samples were then evaluated by eight readers who had no prior knowledge of the Reading Ease Scores.

The readers were research workers who had undergraduate degrees and some graduate school training in both the physical and the social sciences; the reports concerned investigations and experiments in the physical and social sciences. Each reader completed a questionnaire for each sample, in which he stated his opinion both as to the sample's capacity for being understood at one reading and its capacity for being summarized faithfully. The readers also indicated the approximate number of words requiring reference to a dictionary. Finally, the readers assigned a rank order to each sample, indicating how they felt that particular sample compared with the other five in general readability.

The most remarkable result of the test was that the average (mean) rank order of readability assigned by the readers was almost exactly in reverse correlation with the rank order according to the Flesch Reading Ease Scores (see Table 1). It will be observed that the reports rated first and second for readability according to the Flesch system were fourth and third for the six readers. The two selections rated last according to the Flesch system were placed first and second by the readers.

Analysis of the questionnaires showed some correlation between the rank order assigned by the readers

[1] *How to Test Readability*, Harper and Brothers, New York, 1951.

[2] $(RES) = 206.835 - [1.015\,(ASL) + .846\,(NS)]$, where RES is the Reading Ease Score, ASL is average sentence length, and NS is the number of syllables per 100 words.

and their opinion as to ease of summarizing, and somewhat less correlation between that rank order and the opinion concerning capacity for being understood at one reading (see Table 1). No correlation was observed either between the rank order assigned and the number of sentences that had required rereading, or between the order and number of words that had to be looked up in a dictionary (see Table 1).

The results of this admittedly limited experiment suggest that, in scientific writing, there is no correlation between readability as measured by sentence and word length and readability as judged by trained readers. Thus, the current readability measuring systems are based solely on mechanical factors of sentence and word length alone, without considering content or quality of thought. They are apparently not valid for and should not be applied to scientific writing. One can only hope for a more critical examination of the theory that long sentences and long words reduce readability and that, eventually, this theory will no longer inspire arbitrary attempts to alter the style of competent writers generally.

Editor's Note: The Flesch Reading Ease Score for the first four paragraphs of this article is 29.3, which is slightly higher than the mean of the scientific articles compared by the author. It is interesting to note that the first 100 words rated 23.3, or slightly more difficult than the hardest of the technical articles used in the comparison.

TABLE 1

COMPARISON OF FLESCH READING EASE SCORES WITH EVALUATIONS MADE BY ACTUAL SCIENTIST-READERS

Sample Letter	Flesch FRES	Rank in RES	Reader's Rank	Comment on Summary	Comment on Understanding Single Reading	Sentences Requiring Re-reading	Words Requiring Use of Dictionary
F	23.4	5	1	excellent	excellent	moderate	low
E	23.4	5	2	excellent	excellent	low	low
B	28.8	3	3	excellent	excellent	moderate to high	low
C	36.4	2	3	fair	excellent	moderate to high	high
A	45.8	1	4	fair to poor	fair	high	low
D	26.4	4	5	poor	poor	moderate to high	low

"CASE STUDIES" INCREASE INTEREST IN MATERIALS LABORATORY

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That dull course in "materials testing laboratory" can be changed into an interesting and creative contribution to the student's store of knowledge. Too often this potentially great laboratory course becomes a formality of following specific instructions, taking data, and writing reports. The organization of the experiment, the data needed, the original background and preparation, all are missing. When the same experiments are repeated each semester, the instructor finds a direct similarity between the reports received. This indicates that the students are not thinking for themselves, but are leaning on previous reports to do their thinking for them. It is also difficult for the busy instructor to sit down and write a complete new set of experiments each semester without any repetition. As a consequence it seems proper that some way should be found of creating additional experiments without undue expenditure of time. The obvious answer, of course, is to interest the student in writing the procedure for the experiments himself, either on his own or during class periods.

The testing laboratory schedule at Wichita University was recently revised as an attempt to interest students in testing procedure. The class was first divided into two groups, and problems rather than experiments were assigned to each group. Instead of reports, the students in group A were required to write a procedure to be followed by group B at some later date. The problems were composed in a fashion to interest the student in determining why the test was necessary and what results were needed to solve the problem properly.

An example of this type of problem follows:

"A law suit developed over the collapse of a roofing truss. The insurance company refused to pay damages, contending the truss was poorly designed and inadequate to support its own weight. Arguments in the courtroom resolved into how much column load could be applied to the ends of each section of the 4×16 timbers. The judge recessed court and asked you to run tests upon some sample timber taken from the fallen truss. Since there were various lengths of span pieces, you must explain the variation in allowable load with length and section shape. The report must use clear and simple English that the jury of laymen can understand. The collapse of the truss occurred during a rain storm, so the timber could have been saturated at the time of failure. The sample submitted for test is $2'' \times 8'' \times 10'$ and can be cut into any size specimens required. Your problem is to write a procedure for the experiment and explain what results are necessary to satisfy the jury." (Actual court case in

U. S. District Court—DeLuxe Lanes *vs.* Worchester American Insurance Co.)

Under the guidance of the instructor, the procedure-writing group laid out a step-by-step routine for the second group to follow in performing the experiment. The experiment was then carried out by the procedure-writing group according to this outline, and the necessary data were taken. An evaluation was then made by the group on whether the data would produce the desired results, and any suggestions for improvement in the method were discussed. Finally, the group submitted a formal procedure for the second group to follow.

The second group was allowed to make written comments as they followed the procedure submitted by the first group. These comments greatly assisted in grading the report and also in the student's self-evaluation when his turn came to write a procedure. The full report was then written by the second group and re-submitted to the first group for approval.

The viewpoint of the practical application was clearly contained in each problem and was presented to point out some function of testing laboratory work in industry. The knowledge of the audience to which the report was directed gave the students a satisfactory basis for evaluating the ideas presented and for excluding any rambling or unnecessary material. Each problem was planned to familiarize the student with a different phase of testing so the scope of the course would not be changed and the student would get his basic background knowledge through individual problems. An example of this diversification is shown by the experiment dealing with the stress-strain recorder:

"You are employed by a manufacturing plant as head of the testing laboratory. A salesman has proposed that the company purchase an automatic stress-strain recorder for use on your testing machine. Your responsibility is to use the device and your own machine to verify the physical characteristics of the material employed in the saleman's demonstration. You are not trying to sell the equipment, but the decision to purchase will be based largely on your report. The management, of course, has full technical knowledge of your operation; a complete but terse presentation of your findings is desirable. You are to write a procedure for your testing group to follow as they prepare a report on the advantages and accuracy of the equipment."

The above plan has been in operation for two years, and has been a source of satisfaction to all concerned. One of the few difficulties encountered was that occasionally the student writing the procedure expressed himself too vaguely for the experimenters to follow readily. This was overcome to a considerable extent by requiring that an outline of the procedure be included in the report. The outline both improved the report and gave experimenters a clearer picture of the problem.

In preparing these procedures, the students write fewer total reports, but the experience in giving clear instructions more than offsets any lack of practice in composition. The students now ask questions that show interest and comprehension of test methods. Finally, the approach used here, that of writing procedures and executing them, need not be confined to testing, but can be used with equal success in many other laboratory courses.

VOLUMETRIC EFFICIENCY

A Critical Evaluation of an Ambiguous Term

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From the mechanical engineer's viewpoint, one of the most abused concepts in the realm of applied thermodynamics is that of volumetric efficiency. A concept which is basic to the analysis and performance of positive displacement machinery, volumetric efficiency seems to mean a number of different things to different people. Although mechanical engineers feel intuitively that volumetric efficiency is the ratio of the amount of gas drawn into a piston engine or compressor to the displacement of that machine, various sources define the term from conflicting points of view. This lack of uniformity among authors has been a source of confusion to students in successive courses dealing with thermodynamics, heat power, and internal combustion engines.

Compressors

For the analysis of air compressors, most writers define volumetric efficiency as the ratio of free air delivered (in cubic feet) to the piston displacement (cubic feet); free air, of course, is defined as the air drawn through the suction or inlet valves. Some authors, however, define volumetric efficiency as a weight or mass ratio: i.e., the mass of fluid actually inducted per stroke divided by the theoretical mass of fluid required to fill the piston displacement volume under atmospheric conditions. When a perfect gas relationship is assumed, the two definitions are equivalent; nevertheless, the apparent contradiction is an irritation to the student. Also, the conversion from mass to volume implies additional assumptions which are not always obvious.

A more serious disparity lies in the development of either definition into a usable mathematical relationship. The development can be found in any engineering thermodynamics text and will not be included here, but the usual thermodynamic treatment involves the use of several quantities: C = per cent clearance expressed as a decimal fraction; P_1 = the pressure of the fluid in the cylinder at the start of compression; P_2 = the pressure of the fluid at the end of compression; n = a polytropic exponent; and P_a = the pressure of the fluid under "free" conditions.

This last quantity is the major point of contention. When all the quantities are considered, the expression for volumetric efficiency is

$$\eta_v = \frac{P_1}{P_a}\left[1 + C - C\left(\frac{P_2}{P_1}\right)^{1/n}\right].$$

However, some authors completely ignore the effect of throttling across the intake valve and tacitly assume that $P_a = P_1$. Although most thermodynamic studies are based on simplifying assumptions, this one contributes little, if anything, to the analysis. Throttling, or some other significant irreversible expansion, most assuredly does occur across the suction valve, and this fact should be pointed out to the student.

The problem is further confused by failure to distinguish between wet and dry gas. Generally, this distinction is not made in an introductory thermodynamics course, but certainly it should be in subsequent studies. Unfortunately, many authors neglect this phase of the material even when the rest of their analysis is rigorous. All definitions of volumetric efficiency are evasive in this respect, but inasmuch as, say, compressed water vapor is not the desired end product from an air compressor, it may be assumed that bone dry air should be considered. A few psychrometric calculations can yield the desired result. Although the analysis is somewhat more complex than the case of throttling across the intake valve, it should at least be mentioned.

In most instances, neglecting both throttling at the intake and moisture in the gas will not change significantly the magnitude of the volumetric efficiency for any given compressor. The value of more accurate and realistic considerations lies in the training given to the student. He should be made aware of the existence of these factors so that, if the necessity ever arises, he can cope with them successfully. At least he can intelligently neglect their effects rather than be completely ignorant of them.

The case of volumetric efficiency for a piston type internal combustion engine also deserves more consistent and complete treatment by authorities. Here there is reasonable agreement for the air standard engine; the disparities occur for the real engine. Also, for neither engine is any attempt made to develop an expression in terms of clearance and related factors.

Internal Combustion Engines

To illustrate, the following definitions are taken from two popular internal combustion engine texts and an equally popular heat-power text:

"Volumetric efficiency is defined as the ratio of the charge inducted, at the atmospheric conditions surrounding the engine, to the piston displacement. Only the volume of air inducted is considered when using liquid fuel."

"The volumetric efficiency of an engine is defined as the ratio of the actual weight of air inducted by the engine on the intake stroke to the theoretical weight of air that should have been inducted by filling the piston displacement volume with air at atmospheric temperature and pressure."

"Volumetric efficiency may be defined as the quotient of the volume of the combustible charge drawn in, reduced to standard temperature and pressure, divided by the piston displacement. It is really the ratio of the mass of the charge actually drawn in to an ideal mass. The standard conditions may be, 1) 60° F and 14.7 psia, 2) the pressure and temperature of the atmosphere surrounding the engine, or 3) the pressure and temperature at the entrance to the induction pipe."

By contrast the following definition appears in the test code of a large automotive engine manufacturer:

"Volumetric efficiency is the ratio of the volume flow of moist air at the carburetor per unit time to the effective swept volume of the engine in the same unit of time."

As pointed out above, the first two statements are equivalent. The third

definition is different in that the "combustible charge" must necessarily include both air and fuel; the choice of "standard conditions" also leads to an ambiguity. The last statement is still further away from the others, in that "moist air" (presumably humid) is specified; furthermore, the condition of the air at the carburetor could be different from the air in some other area adjacent to the engine. Unfortunately, the Society of Automotive Engineers does not deal with volumetric efficiency, so that none of the above can be corroborated by any accepted authority.

Once again, it should be pointed out that the differences in results are not great. Yet it is regrettable that this lack of agreement exists, for it can lead the student to a mistaken concept of volumetric efficiency.

A striking example can be found in a problem (with answer), which appears in a recent edition of another heat-power text. The problem appears at the end of the chapter on internal combustion engines, in which the various performance characteristics are discussed. One of the characteristics is volumetric efficiency, described as the ratio of the actual weight of air inducted to the weight of free air equivalent to the piston displacement.

The problem asks for the bore and stroke of a multicylinder four-stroke cycle engine, and the following information is given: brake horsepower output, average piston speed, volumetric efficiency, mechanical efficiency, heating value of gasoline, theoretical air-fuel ratio (on weight basis), per cent excess air, brake thermal efficiency, stroke-bore ratio, ratio of densities of gasoline vapor to air, and the pressure and temperature of the air and gasoline vapor at the end of the the suction stroke.

This is truly a splendid problem. It requires a good deal of careful, analytical thought. The student cannot plunge wildly into a haphazard solution, nor can he refer to any examples included in the text to parrot a solution. He must sift the data, rearrange so that they will yield additional information, and then carry through to a solution. The problem is as thorough as it is basic, and the author deserves credit for having formulated it.

When a text problem is as rigorous as the one in question, it is frequently advisable to include the answer so that the student will recognize whether or not both his method and calculations are correct. Unfortunately, in this particular illustration the answer given is *incorrect* by a factor equal to the volumetric efficiency. From the statement of the problem, the volumetric efficiency does not even enter into the solution. The actual weights of air and fuel per unit time can be easily found, as can the specific volumes of these fluids in cylinder. From this information the total volume swept per unit time follows directly. This can be expressed in terms of bore, stroke, and engine speed, and the desired answer can then be found with little difficulty.

Whoever solved this problem apparently did not have a clear understanding of volumetric efficiency. If he had, he would have recognized that volumetric efficiency was not a consideration if for no other reason than that the properties of "free air" were unknown. From the author's

definition of volumetric efficiency, atmospheric pressure and temperature are necessary antecedents to finding the volume of free air.

In many instances, authors will compose the problems and then assign graduate students or advanced undergraduates the labor of finding the answers. This procedure generally proves satisfactory to all concerned, for the student learns a good deal from his experience and the author is spared the tedium of a very routine task. However, it is imperative that the student be well founded in the subject and understand all of the concepts—which were lacking here.

Summary

Although volumetric efficiency can logically be only a single concept, it seems to have been presented under several different interpretations. So long as these divergencies or contradictions are continued, the student will encounter difficulties which may completely obscure more important considerations. It can only be hoped that something constructive will be done to alleviate the situation. Pending action by some standardization committee or code organization, however, instructors in the appropriate subjects should at least note the problem, and should clarify it as best they can.

MOTION AND TIME STUDY INTENSIVE COURSE

Washington University of St. Louis, Department of Industrial Engineering, will present a Motion and Time Study Intensive Course from June 6 through June 15. The course will help those attending to apply motion and time study in their own organizations and to train other persons in conducting such studies. The material presented will emphasize establishing correct procedures before work is started, as well as improvement of existing methods. Further information can be obtained from the Department of Industrial Engineering, Washington University, St. Louis 5, Missouri.

TORGERSEN HONORED

The Heights Alumni Association of New York University recently honored Harold Torgersen, a member of the ASEE since 1935, for twenty-five years of service to NYU. Former chairman of the Evening Education Division of ASEE, Professor Torgersen is Assistant Dean of the College of Engineering, and Professor of Electrical Engineering.

GRAPHIC SCIENCE

Analysis—Synthesis—Communication

Sponsored by the Division of Engineering Drawing
Editor: Albert Jorgensen, University of Pennsylvania

Report on the Midwinter Meeting of the Division

The Annual Midwinter Meeting of the Engineering Drawing Division held at the Illinois Institute of Technology was highly successful. The program included interesting and stimulating papers. Topics discussed including drawing courses for students majoring in science, nomography, the relations of drawing and design, and the problems of simplified drafting.

Chicago lived up to its reputation as a convention city, and a new attendance record was set for the Division. At least twenty-two states and one province of Canada were represented. Total registration exceeded 180, topping the previous high (set also at Chicago), when one hundred fifty-five registered for the Midwinter Meeting at the Navy Pier Branch of the University of Illinois several years ago. Among those present were W. Leighton Collins, Secretary of ASEE, and E. C. McClintock, Jr., Editor of the Journal of Engineering Education. This display of interest on the part of these representatives of the parent society is sincerely appreciated by the officers and members of the Division.

At the meeting of the Executive Committee of the Division, reports of committees were received, and the following items approved, (1) changing the name of the T-Square Page to that used in this issue, (2) the dates, January 30–February 1, 1957, for the next Midwinter Meeting, to be held at Rice Institute in Houston, Texas, and (3) the arrangements for the 1956 Summer School (given below). It was also announced that the 1958 Midwinter Meeting will be held at the General Motors Institute, Flint, Michigan.

You are urged to "AIM FOR AMES" plenty early so that you can attend the entire Summer School for Engineering Drawing, which will be held at Iowa State College. Two hundred members are expected to be present. The School starts with registration Wednesday afternoon, June 20, 1956, and extends through Wednesday afternoon, June 27. Note that these dates overlap those for the Annual Meeting of the Society, which will be held at the same institution on June 25–29.

The program for the School is being developed under the direction of William E. Street, Chairman of the Division, with Professor James S. Rising of Iowa State College in charge of the local arrangements. (The January, 1956, issue of the Journal gives information concerning the host institution.) U. S. highways 30 and 69 and the Chicago and North Western Railroad run through Ames. If traveling by air, members of the Drawing

Division may make arrangements with Jim Rising, at Iowa State College, to have a car meet them at the Des Moines airport, thirty-two miles south of Ames, for transportation to the campus. Ample housing is available in dormitories (Jim says they are good), hotels, and motels. There will be sufficient time for pre-registering and making housing reservations after you receive the final program.

The headquarters for the School will be in Room 403, Marston Hall, and sessions will be held in the auditorium of the Electrical Engineering Building nearby. Registration will open 4 P.M.–6 P.M., Wednesday, June 20, in the Memorial Union Building.

The theme of the School will be "Evaluation of Engineering Drawing for the Future." A preliminary outline of the program follows.

Program for the Summer School on Engineering Drawing Iowa State College, June 20–27, 1956

Thursday, June 21

9 A.M. Address of Welcome and Response

Objectives of Engineering Drawing in Engineering Education
R. R. Worsencroft, *University of Wisconsin*

Correlation of Engineering Drawing Courses
I. L. Hill, *Illinois Institute of Technology*

2 P.M. Motivation Needed in Teaching Engineering Drawing
E. D. Black, *General Motors Institute*

Drawing and Descriptive Geometry Courses Which Comply With the ASEE Evaluation Report
R. A. Kliphardt, *Northwestern University;* H. C. Spencer, *Illinois Institute of Technology;* J. T. Rule, *Massachusetts Institute of Technology;* C. J. Vierck, *Ohio State University*

7 P.M. Orientation as a Function of Engineering Drawing
S. P. Owen, *Rutgers University*

Industrial Planning and Design as They Relate to the Drawing Room
J. A. Carroll, *The Proctor and Gamble Company*

Friday, June 22

9 A.M. Creative Problems for Basic Engineering Drawing
Matthew McNeary, *University of Maine*

A Damper on American Scientific Progress
R. W. Pearson, *Radio Corporation of America*

Graphics and the John Deere Cotton Picker Spindle
C. Gordon Sanders, *Iowa State College*

What You Will See at the John Deere Des Moines Works
Bud C. Lundahl, *John Deere Plant Superintendent*

1 P.M. Inspection trip to the John Deere Des Moines Works

7 P.M. Dinner, Ladies Invited

DRAWING OF TOMORROW
B. L. Wellman, *Worcester Polytechnic Institute*

A SURPRISE!

Saturday, June 23

9 A.M. SIMPLIFIED DRAFTING AS PROPOSED BY THE BUREAU OF SHIPS
R. Wallace Reynolds, *California State Polytechnic College*

DIMENSIONING FOR MASS PRODUCTION
P. G. Belitsos, *General Electric Company*

DIMENSIONING AND CHECKING OF DRAWINGS
H. C. Hesse, *Valparaiso University*

2 P.M. HOW TO MAKE AND USE TEACHING AIDS
R. I. Hang, *Ohio State University*

THE PRINTED CIRCUIT
W. J. Adams, *Bell Telephone Laboratories*

EXAMINATIONS IN DRAWING AND DESCRIPTIVE GEOMETRY
Irwin Wladaver, *New York University*

6:30 P.M. Executive Committee Dinner

Sunday, June 24

3–6 P.M. Reception at the home of James S. Rising

Monday, June 25

9 A.M. CHANGES IN THE ASA DRAFTING STANDARDS
R. P. Hoelscher, *University of Illinois*

AMERICAN DRAFTING STANDARDS IN BASIC DRAWING COURSES
R. S. Paffenbarger, *Ohio State University*

CHANGES IN DRAWING EMPHASIS
R. T. Northrup, *Wayne University*

2 P.M. MOVABLE SCALE NOMOGRAPHS
J. N. Arnold, *Purdue University*

A LESSON IN NOMOGRAPHY
A. Jorgensen, *University of Pennsylvania*

GRAPHICAL CALCULUS
E. M. Griswold, *The Cooper Union*

Tuesday, June 26

2 P.M. Joint Conference with English Division

ESTHETIC FUNCTIONS OF ENGLISH
James H. Pittman, *Newark College of Engineering*, and Frederic H. Higbee, *State University of Iowa*

ESTHETIC FUNCTIONS OF ENGINEERING DRAWING
Wayne L. Shick, *University of Illinois*

A GRAPHIC APPROACH TO ENGINEERING EDUCATION
Frank A. Heacock, *Princeton University*

6 P.M. Dinner, Ladies Invited
Nomography Award ($100 for the best Nomograph of the year)
The Distinguished Service Award of the Drawing Division

MAKING FACES
Herbert V. Hake, *Iowa State Teachers College*

Wednesday, June 27

12 Noon Luncheon and Business Meeting

2 P.M. Joint Conference with the Mathematics Division

A GRAPHICAL APPROACH TO THE STUDY OF CALCULUS
John F. Calvert, *University of Pittsburgh*

AN OPERATIONAL SYMBOLISM FOR GRAPHICAL PROCESSES
S. A. Coons, *Massachusetts Institute of Technology*

GRAPHICAL ANALOGUES OF MATHEMATICAL PROCESSES
J. F. Twigg, *Massachusetts Institute of Technology*

REVISED ASTE DATA SHEET NUMERICAL INDEX

The National Standards Committee of the American Society of Tool Engineers has recently made available a revised Data Sheet Numerical Index adapted from the U. S. Standard Commodity Classification System. The Index is intended to aid the tool engineer in selecting, filing, classifying, and comparing descriptions of all available tool engineering products. The Index comes in two parts: a Numerical Listing which shows the basic seven-figure decimal arrangement, and the Alphabetical Listing, a subject-cross-referencing of the numerical material. Further information can be obtained from the National Standards Committee, American Society of Tool Engineers, 10700 Puritan Avenue, Detroit 38, Michigan.

. . . . . YET-ITUDES

VIEWS AND NEWS CONTRIBUTED BY

The Young Engineering Teachers

JOHN L. ARTLEY, Chairman
Duke University

HAROLD A. FOECKE, Editor
University of Notre Dame

SUMMER EMPLOYMENT– A BUSMAN'S HOLIDAY

Every year about this time many engineering teachers, especially the younger ones, concern themselves about summer employment. That summer employment in industry is one very important and profitable form of the various types of industrial experience for engineering faculty members is affirmed by articles in the JOURNAL in recent years. These same articles indicate that it is also profitable to industry because for various reasons, ranging from the critical shortage of engineering talent to enlightened public relations, opportunities for summer employment are on the increase.

The purpose of these few paragraphs is to propose an additional benefit: that some companies might find it very profitable to employ college faculty members during the summer, not for research or design work, but for teaching. Specifically, they could offer flexible short courses for the young company engineers, who would thereby become more productive for the company and also continue to grow professionally. The following paragraphs will attempt to buttress this proposal with statements designed to show the possible benefits to be derived from such courses by the young engineer, by the company and by the teacher.

The banner cry today is "Fundamentals," stress the science of engineering, concentrate on basic principles, de-emphasize the less stable applications and current practices. This principle has been urged frequently by industrial and educational leaders, and also by all the major studies of engineering education in the past two decades. It must be recognized, however, that while this is the best possible preparation for long range professional needs, the student's immediate productivity after graduation is necessarily somewhat diminished. The new graduate is faced with a somewhat longer transition period before he reaches full professional stature in any specialty than might have been the case if certain senior courses had been tailored to prepare him for such specialized work.

This transition phase, the first five years, is a critical time for the young engineer. While the final responsibility for professional development

naturally rests upon the engineer himself, it has been recognized that the employers of these young men do have responsibilities in fostering professional growth. Apparently new employees in most of the larger industries are at least partly provided for by the organized training programs which these companies already have.

The employees of medium or smaller sized companies are not always so fortunate, and the fact that men in smaller organizations sometimes have closer contact with superiors does not always offset the lack of a thorough and well-planned training program. What a boon it would be to such young engineers if summer programs could be developed to give them some of the more specialized knowledge they need to be productive, and to promote their professional growth and development!

There are many good reasons which in the past have kept smaller companies from establishing organized and formal training programs. But equivalent results could readily be obtained if engineering teachers, especially young engineering teachers, would take the initiative (with company support) in designing summer courses to fit the needs of young engineers.

Such an arrangement would have several advantages. It would give the companies an opportunity of fulfilling an obligation to their employees and still of benefiting from increased productivity. This could be done without asking any of their regular senior staff to drop or curtail their work for the "luxury" of giving some course, not to mention the fact that such staff members, however well qualified technically, simply might not enjoy, or have time for, teaching.

What could be less disrupting of normal routine and more convenient to all than bringing in for a short period a qualified man who has dedicated his life to teaching engineering? Viewed as part of an annual budget, his consulting fees would surely be insignificant in comparison to the benefits derived by getting together a company and a teacher both having imagination and ingenuity.

But, would engineering teachers want to "get away from it all" by going to industry for a summer to *teach*, a busman's holiday if ever there was one? A little reflection indicates, however, that there may very well be some very good reasons why teachers might aspire to do just that. It borders on belaboring the obvious to state that there are many different types of engineering teachers, performing reasonably distinct functions in the whole of engineering education. Such teachers might also profit from varied industrial experiences in research, design, or administration.

And why not teaching? Assignment to work on some particular phase of one particular project may be very rewarding to both teacher and employer. But, while bringing the teacher up to date technically in some necessarily restricted area, which is good, it sometimes runs the risk of being a rather isolated piece of experience, making it difficult to extrapolate the benefits to more general problems in engineering education. On the other hand, how better to get a broad sample of the problems which young engineers face than by working very closely with them in solving these problems through a teacher-student relation? The faculty members will thereby encounter and become acquainted not only with the newest technical developments and problems

(the better to teach specific courses) but also derive a broader base of experience with the more general problems facing young engineers (the better to provide general advice and counsel for undergraduates).

In addition, the added challenges inherent in such a situation make it particularly attractive to some teachers. There are many aspects of teaching in the typical academic environment which teachers view with mixed emotions. What teacher has not felt that his students were working for artificial goals such as grades, honors and awards, or simply to get by, viewing each course as another obstacle which a sadistic administration has placed in the way of that all-important diploma? Students are seldom self-motivated because it is hard for them to sense the relevance of what they happen to be doing to what they will be doing after graduation.

Do Quizzes Help?

The student sees the periodic quizzes and examinations not as a means of self-evaluation of progress, but as so many pedagogical traumatic experiences. Then, too, the sections are frequently much too large for effective personal contact with the individual student and his difficulties. And if, perchance, some class develops a high interest in some particular topic and is anxious to explore it in greater detatil, the teacher is cast in the role of a "cold water merchant," forced to quench the coals of curiosity because, he still realizes that his course is a prerequisite to others and he must cover certain material in fairness to his colleagues. And, finally, the students are to a certain degree a captive audience, relatively incapable of communicating effectively to the right people their praise of the superior or criticism of the mediocre teachers. They go to the good and fair teachers alike, for they have few alternatives.

Fancy now if you can a situation less encumbered by these obstacles to true learning. With a little imagination and resourcefulness, would it not be possible for short courses in industry to make great strides in shucking off these impediments? Now employed, the students could be self-motivated, responsible for evaluation of their own progress and could come if the teacher was effective, could avoid him if not. Individual attention could be given to each student's unique educational needs. It sounds almost too good to be true! Surely a teacher would find such summer experiences invigorating!

So let us have more of these flexible and versatile summer courses in industry. It seems that they could both provide immediate returns and enhance the long-range professional development of the young engineer. They could be a way for some types of companies to profit technically while discharging their responsibilities to their young employees. Finally, such courses could provide very valuable experience for the teacher to take back to his college or university work, providing him with an atmosphere in which he could charge his educational batteries to withstand the steady drain of the typical college session. This kind of busman's holiday for engineering teachers ought to be more clearly recognized and exploited as an important, rewarding, useful, and profitable form of summer work for college faculties. H. A. F.

TEACHING POSITIONS AVAILABLE

ASSISTANT PROFESSOR OR INSTRUCtor to teach fundamental Electrical Engineering courses in Midwest Engineering College. M.S. degree or teaching experience desirable. Position available January 1, 1956 or later. Good salary for qualified person. MAR-2

PROFESSOR OF HEAT POWER OR Fluid Mechanics, interested in assuming department headship; experienced teacher, doctor's degree preferred. Wanted by eastern metropolitan ECPD-accredited college for September, 1956, or sooner if available. MAR-3

ENGINEERING FACULTY OPPORTUnities at midwest college. Chairmanship of the Physics Department, salary open. Also opening for Electrical Engineering Instructor or Assistant Professor in Power Field. Mechanical Engineering Instructor or Assistant Professor in Heat Power and Engineering Mechanics. Instructor or Assistant Professor in Physics. Opportunity for graduate study. Housing available. Appointments to begin September, 1956. MAR-4

ASSISTANT, ASSOCIATE, OR FULL Professor (rank depends upon training and experience) to teach Chemical, Civil, Electrical, and Mechanical Engineering courses. Individuals who desire to do research as well as teaching are desired. Opening September 1, 1956, or sooner. Location Southeast. MAR-5

ASSISTANT PROFESSOR AND INSTRUCtor at growing midwest engineering college in Department of Mechanical Engineering, effective fall semester 1956–57. Assistant Professor must have special experience or training in machine design. Teaching assignment for instructor would include: Heat-Power, Manufacturing Processes, and Laboratory. Salary in both grades dependent upon qualifications. MAR-6

INSTRUCTOR OR ASSISTANT PROFESsor to teach Electrical Engineering courses in a southeastern university. Instructor may obtain M.S., for Assistant Professor M.S. required. Extra income for regular summer school. MAR-7

INDUSTRIAL ENGINEER NEEDED CApable of organizing and teaching Industrial Engineering on the undergraduate level in a regular Mechanical Engineering degree program. Should be active in teaching and professional organizations. Salary and academic rank depending upon degrees and experience. Location, Ohio. Appointment to begin September, 1956. MAR-8

HEAD OF OFFICE EXTENSION SERVices in the Institute of Technology, State College of Washington, Pullman, Washington. Rank of Associate Professor or equivalent, salary for eleven months. Appointment effective July 1, 1956. Additional information may be obtained by writing G. A. Riedesel, Secretary, Committee for Industrial Services, 159 Engr. Lab. Bldg., W. S. C., Pullman, Washington.

ASSISTANT PROFESSORS AND INstructors in Electrical and Mechanical Engineering wanted by the College of Engineering, Marquette University, Milwaukee 3, Wisconsin. Salary commensurate with qualifications. M.S. or work toward it desirable. Opportunity for part-time graduate work at state university. Please forward complete details of education, experience, and personal background to respective department chairmen.

HEADSHIP OF INDUSTRIAL ENGIneering department. Requires background of professionally responsible management position in industry or government, plus good record of publications. Research and teaching experience desirable. Age range 35–50; salary open; position to be filled before September, 1956. Write Chairman, Nominating Committee, Industrial Engineering Department, Pennsylvania State University, University Park, Pennsylvania.

ASSISTANT PROFESSORS, INSTRUCtors, Research Assistants, and Graduate Assistants needed in Engineering Mechanics. Excellent opportunities for graduate work. Write Joseph Marin, College of Engineering, The Pennsylvania State University, University Park, Pennsylvania.

ELECTRICAL ENGINEERING STAFF opening at Colorado A & M College, Fort Collins, fall 1956. Healthful climate, good schools. Expanding department, new building fall of 1957. Nine months appointment, rank and salary commensurate with qualifications. Write Head, Department of Electrical Engineering.

TEACHING POSITIONS IN ENGINEERing technology; teaching and industrial experience desirable. B.S. or M.S. degrees. Cooperative program—Physics, Mathematics, Engineering Drawing, Machine Design, Strength of Materials, Tool Design. Positions beginning September, 1956. Sinclair College, 117 W. Monument Ave., Dayton 2, Ohio.

ASSISTANT DEAN OF ENGINEERING, Master's degree preferred but not required. Salary to depend upon qualifications. Apply to: Dean W. A. Patterson, Fenn College, Cleveland 15, Ohio.

ENGINEERING MECHANICS AND Civil Engineering teachers urgently needed to begin about September 15, 1956. Write to J. H. Murdough, Head, Civil Engineering Dept., Texas Technological College, Lubbock, Texas.

SIX OPENINGS IN ELECTRICAL AND Mechanical Departments. Teaching Assignments: Electric Power, Electronics, Physics, Heat Power, Engineering Drawing, other Mechanical Engineering subjects. Salary depends upon qualifications. Excellent fringe benefits. M.S. in E.E. or M.E. desired. Applicants with B.S. considered. Write to Earle M. Morecook, Chairman, Applied Science Division, Rochester Institute of Technology, Rochester 8, New York.

ENGINEERING FACULTY MEMBER TO head newly authorized Electrical Engineering Department. Candidate should have M.S. or Ph.D. degree, with teaching and professional experience. Position to be filled before September, 1956. Salary open. Write to R. E. Gibbs, Dean, College of Engineering, Bradley University, Peoria 5, Illinois.

ENGINEERING DRAWING INSTRUCtor starting July or September, 1956. Ideal college town in the Rocky Mountains. Write to Head, Department of Mechanical Engineering, Montana State College, Bozeman, Montana.

ELECTRICAL ENGINEERING POSItion to teach undergraduate courses. M.S. required. Opportunity for graduate study, industrial consulting, or research. Rank and salary open. Start February or September, 1956. University of Santa Clara, Santa Clara, California.

MECHANICAL ENGINEERING POSItion open, Master's degree or higher, some teaching or industrial experience. Grade and salary dependent on qualifications. Nine months per year. Also Agricultural Engineering position to teach farm structures and machinery and power courses, as well as general engineering courses. Instructor or Assistant Professor rank. Salary commensurate with qualifications. Nine month appointment. Complete new Engineering Center under construction this spring. High and dry climate, no traffic or smog, good schools, lots of elbow room, not an A-bomb target. Write Dean of Engineering, Colorado A & M College, Fort Collins, Colorado.

TO CONDUCT INDUSTRIAL MANAGEment major in small college. Teach 12 hours including Industrial Management course; other courses depending on training, experience, and preference. Outside consulting allowed. Rank and salary according to degrees and experience. Send resumé to Robert J. Moore, Utica College of Syracuse University, Utica, New York.

CHRYSLER INSTITUTE OF ENGINEERing again has openings on its full-time teaching staff. For: supervisor of engineering graduates working on individual automotive design projects as a part of their Graduate School course. Duties would also include supervision of graduate classwork. Desired qualifications are age 25–40; B.S. degree or higher in engineering; at least 2 years of college teaching experience; some design experience, preferably automotive. Also a teacher and supervisor of Graduate School classwork. Qualifications are age 25–40; M.S. degree in engineering; experience in teaching Mechanical Engineering subjects. Write to Chrysler Institute of Engineering, Att: L. R. Baker, Director, P. O. Box 1118, Detroit 31, Michigan.

INSTRUCTOR AND ASSOCIATE PROFESSOR positions open in Mechanical and Civil Engineering, beginning September, 1956. Rapidly growing school. Write to Executive Dean, Fresno State College, Fresno, California.

INSTRUCTOR AND ASSISTANT PROFESSOR in Engineering Drawing and Descriptive Geometry for September, 1956. Assistant Professor's rank requires Master's degree. Retirement age of 70 offers opportunity for additional years of teaching to those forced to retire elsewhere at 65. Apply to Dean James R. Cudworth, College of Engineering, University of Alabama, University, Alabama.

CIVIL ENGINEER—TO TEACH SURveying, Highways, Fluid Mechanics, Materials Testing, and Civil Engineering laboratories. Should have M.S. or Ph.D., be active in technical and professional organizations. Salary and rank open depending upon degree and experience. Position starts September, 1956. Location, Ohio. MAR-9

COMBINED TEACHING AND APPLIED Research positions in Physics, Electronics, and Mechanical Engineering. Contract research for industry and military. Ph.D. or M.S. required. Salaries comparable to industrial. Staff encouraged to develop own research project ideas for sponsorship. Write to Assistant Director, Denver Research Institute, University of Denver, Denver 10, Colorado.

CONSTRUCTION EDUCATION SUMMER SCHOOL

Ames, Iowa, June 29-30 and July 1, 1956

The Civil Engineering Division announces a Summer School on Construction Education in conjunction with the ASEE Annual Meeting at Iowa State College. Conceived as a device for giving impetus and direction to the growing interest in construction education throughout the country, this Summer School will bring together representatives of education and industry to exchange views and experiences and to develop programs of cooperation and action.

Friday Afternoon—Construction Industry Presentation

Contractors Look at Engineering Education
What Contractors Expect of Engineering Graduates
Summary of the "National Conference on Construction Operations" held in Los Angeles in January, 1956

Friday Evening—What Education Framework?

Construction Option in Civil Engineering
Construction Option in Architectural Engineering
Construction Engineering Curriculum
Graduate Study in Construction
Technical Institute Program

Saturday Morning—What Special Subjects

Methods and Equipment
Costs and Estimates
Construction Planning and Management

Saturday Afternoon—How Can Industry Contribute?

How AGC Chapters Can Assist the Engineering Colleges
How Building Contractors Can Help
Panel Discussion

Sunday Morning—General Discussion

Needs of Construction Industry for Engineers
Challenge to Engineering to Embrace the Field of Construction Management
What Special Construction Education is Needed?
What New Developments Will Influence Tomorrow's Construction?
How Can the Construction Industry Best Aid and Guide Students and Faculties?
What Are the Needs for Methods Research?

Recess for Church

Sunday Afternoon—Consideration of Resolutions

Resolutions Committee to introduce resolutions expressing consensus of delegates on important points

Discussion and action on resolutions

Speakers and discussion leaders include outstanding persons from the construction industry and from construction engineering education.

The program has been developed by Committee 6, Construction, of the Civil Engineering Division of ASEE, under the Chairmanship of C. Martin Duke, Professor of Engineering, University of California, Los Angeles. Committee members are H. B. Blodgett, University of Nevada; A. N. Carter, Associated General Contractors; A. L. Chambers, University of Kentucky; Ellis Danner, University of Illinois; E. E. D'Appolonia, Carnegie Institute of Technology; P. F. Keim, University of California at Berkeley; J. A. Oakey, North Dakota Agricultural College; J. J. Kennedy, N. O. Naval Base, and W. T. Hosmer, Iowa State College.

Details of the sessions and arrangements will be given in the *Civil Engineering Bulletin*, and in the final program of the annual meeting.

NEW MEMBERS OF THE ASEE

ARGES, K. PETE, Assistant Professor of Civil Engineering, Duke University, Durham, North Carolina. Edward K. Kraybill, Paul C. Stottlemyer.

BALL, LLOYD D., Instructor Engineering Drawing and Machine Design, University of Colorado, Boulder, Colorado. C. L. Eckel, F. S. Bauer.

BANNON, ROBERT E., Associate Professor in Metallurgy, Mechanical Engineering, Newark College of Engineering, Newark, New Jersey. G. B. Thom, I. P. Orens.

BARNES, EDWARD M., Associate Professor, School of Technical Training, Oklahoma A. & M. College, Stillwater, Oklahoma. H. P. Adams, Hugh Lineback.

BAXTER, WYLEY L., Associate Professor in Graphics, United States Air Force Academy, Aurora, Colorado. James S. Barko, Archie Higdon.

BISSIRI, AUGUSTO, JR., Instructor of Engineering, Los Angeles City College, Los Angeles, California. B. W. Martin, A. L. Eller.

BLACK, LOREN T., Instructor of Mathematics, Long Beach City College, Long Beach, California. D. M. Wilson, D. L. Trautman.

BOND, ROBERT EDWARD, Assistant Professor in Drawing, College of Technology, University of Houston, Houston, Texas. Joseph A. Bennett, Charles P. Hayes.

BRANDENBURG, PATRICK FISK, Assistant Professor of Mechanical Engineering, University of Wichita, Wichita, Kansas. John W. Dunn, L. U. Rastrell.

BRANDS, FRANK WILLIAM, Instructor in Electrical Engineering, Washington State College, Pullman, Washington. E. G. Ericson, A. L. Betts.

BRINKMANN, THOMAS HENRY, Assistant Professor in Industrial Relations, Northwestern University, Evanston, Illinois. C. E. Watson, P. W. Erb.

BROWN, ELLSWORTH ALLEN, JR., Instructor of Mechanical Engineering, Northwestern University, Evanston, Illinois. R. L. Young, E. F. Obert.

BULLIS, WILLIAM R., Instructor of General Engineering, Hartnell College, Salinas, California. C. E. Cherry, D. L. Trautman.

BURGER, WILLIAM, Dean of Students, Colorado School of Mines, Golden, Colorado. F. R. Campbell, William J. Chapitis.

BURNER, CHARLES E., Lt. Col., Signal Corps, Head, Military Science Department, Worcester Polytechnic Institute, Worcester, Massachusetts. M. M. Boring, A. Bronwell.

CHILDS, RALPH DE S., Associate Professor of Humanities, The Cooper Union, Cooper Square, New York, New York. W. B. Eubler, R. W. Cumberland.

CLOTHIER, ROBERT F., Administrator, Technical Training, Westinghouse Atomic Power Division, Clairton, Pa. John R. Van Horn, D. J. Ford.

COTELLESSA, ROBERT F., Assistant Professor of Electrical Engineering, New York University, New York, New York. J. H. Mulligan, G. Gerard.

CROSBY, HERBERT A., Instructor, Electrical Engineering Department, Washington University, St. Louis, Missouri. R. J. W. Koopman, P. M. Honnell.

DAVISON, FRANK L., Methods Engineer at The Formica Company and instructor at Ohio Mechanics Institute, Cincinnati, Ohio. Paul K. Johnston, E. M. Brodt.

DAY, DAVID A., Assistant Professor of Civil Engineering, University of Illinois, Urbana, Illinois. Thomas C. Shedd, Ellis Danner.

DENNING, MERLE ARTHUR, Head of Mechanical Drawing Department, Tucson Senior High School, Tucson, Arizona. M. L. Thornburg, H. A. Marcoux.

DE RIVERA, HORACE LELAND, Lecturer of Mathematics, Northeastern University, Boston, Massachusetts. C. H. Berry, A. R. Foster.

DRYDEN, CHARLES E., Associate Professor of Chemical Engineering, The Ohio State University, Columbus 10, Ohio. J. H. Koffalt, Aldrich Syverson.

DUFFY, EUGENE B., Engineer, Engineer Research and Development Laboratories, Fort Belvoir, Virginia. E. E. Pickard, T. R. Jones.

DYCHE, HOWARD EDWARD, JR., Instructor, Pennsylvania State University-McKeesport Center, Pittsburgh, Pennsylvania. V. E. Neilly, M. Levine.

EDLUND, CHARLES F., Dean of Faculty, Lowell Technological Institute, Lowell, Massachusetts. Milton Hindle, M. E. Gelinas.

ELDRIDGE, WINFIELD H., Instructor of Civil Engineering, University of Illinois, Urbana, Illinois. M. O. Schmidt, Charles S. Danner.

EVANS, DAVID A., Supervising Engineer, Technical Publications Department, National Tube Division, Pittsburgh 30, Pennsylvania. W. Leighton Collins, W. M. Lansford.

FEDELL, RICHARD L., Instructor, School of Engineering, Colorado A. & M. College, Fort Collins, Colorado. Harold B. Mummert, Harry G. Lorsch.

FOSTER, CHESTER, Instructor, Engineering Drawing, Iowa State College, Ames, Iowa. James S. Rising, Charles G. Sanders.

FOX, JAY, Instructor of Engineering, West Contra Costa Junior College, Richmond 10, California. Douglas Connelly, Lloyd E. Clifford.

GEORGE, ROBERT B., Educational Adviser, Department of Extension Instruction, The Engineering School, Ft. Belvoir, Virginia. Edward E. Pickard, T. R. Jones.

GOLDMAN, JAY, Lecturer in Industrial Engineering, Washington University, St. Louis, Missouri. D. A. Fischer, G. Nadler.

GOODMAN, THOMAS P., Assistant Professor of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge 39, Massachusetts. J. L. Shearer, C. Richard Soderberg.

GRAU, HERMAN, Assistant Professor of Mechanical Engineering, Polytechnic Institute of Brooklyn, Brooklyn, New York. Charles E. Schaffner, Albert D. Capuro.

HAMILTON, HOWARD BRITTEN, Assistant Professor of Mechanical Engineering, University of Wichita, Wichita, Kansas. John W. Dunn, E. L. Cook.

HARTZ, BILLY J., Assistant Professor of Civil Engineering, University of Washington, Seattle, Washington. J. A. Higbee, J. E. Colcord.

HAUSER, NORBERT, Instructor of Industrial Engineering, New York University, New York 53, New York. Norman N. Barish, A. W. Rathe.

HEAD, ROBERT R., Associate Professor of Mechanical Engineering, University of Alabama, University, Alabama. L. B. Almy, F. W. Candel.

HIXSON, A. NORMAN, Assistant Vice President, Engineering Affairs, University of Pennsylvania, Philadelphia 4, Pennsylvania. M. C. Molstad, C. C. Chambers.

HOLMES, DANIEL JOHN, Instructor in Drawing, Milwaukee School of Engineering, Milwaukee, Wisconsin. C. O. Werwath, F. H. Kaufmann.

HOYT, BERNARD W., Instructor, Industrial Engineering, Syracuse University, Syracuse, New York. R. P. Lett, Bert H. Norem.

HUANG, T. C., Assistant Professor in Mechanical Engineering, Oregon State College, Corvallis, Oregon. L. Slegel, W. H. Paul.

HUBBARD, PHILIP GAMALIEL, Assistant Professor of Mechanics and Hydraulics, State University of Iowa, Iowa City, Iowa. D. W. Appel, H. Rouse.

HUMBLE, M. KEITH, Director of Vocational Technological Institute, Southern Illinois University, Carbondale, Illinois. W. Leighton Collins, C. E. Kesler.

HUNTER, HOWARD L., Dean, School of Arts and Sciences, Clemson Agricultural College, Clemson, South Carolina. James H. Sams, K. W. Rausch.

JOHNSTON, ALBERT M., Staff Supervisor, Technical Recruitment, Westinghouse Bettis Plant, Pittsburgh, Pennsylvania. John R. Van Horn, W. W. Culbertson.

JOSEPH, DAVID, Instructor of Electrical Engineering, Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, Pennsylvania. J. B. Brainerd, R. M. Showers.

KIMBALL, DEAN E., Assistant Professor of Electrical Engineering, Antioch College, Yellow Springs, Ohio. Robert A. Voelker, Donald J. Myatt.

LAUSCHE, LUVERNE FREDERICK, Business Manager and part-time Associate Professor of Mechanical Engineering, Ohio University, Athens, Ohio. E. J. Taylor, P. H. Black.

LEVIDOW, WILLIAM, Instructor in Electrical Engineering, Newark College of Engineering, Newark, New Jersey. R. E. Anderson, D. W. Dickey.

LIENHARD, JOHN H., JR., Instructor of Mechanical Engineering, University of Washington, Seattle 5, Washington. Donald D. McNeese, James B. Morrison.

LENZEN, KENNETH H., Associate Professor of Applied Mechanics, University of Kansas, Lawrence, Kansas. Kenneth C. Deemer, Thurmul F. McMahon.

LONG, CARL F., Instructor in Civil Engineering, Thayer School of Engineering, Hanover, New Hampshire. S. Russell Stearns, W. P. Kimball.

LUFKIN, JAMES MARKHAM, Instructor of English, University of Minnesota, Minneapolis, Minnesota. L. O. Guthrie, H. E. Sauter.

MACCARONE, MICHAEL B., Instructor, Mechanical Engineering, New York University, College of Engineering, New York, New York. Jack Como, Walter L. Schneider.

MADISON, M. LESLIE, Associate Professor of Mathematics, Colorado A. & M. College, Fort Collins, Colorado. N. A. Evans, H. H. Schweizer.

MARCHAND, ARTHUR J., JR., Instructor, Mechanical Engineering Department, Northeastern University, Boston, Massachusetts. Arthur R. Foster, A. J. Ferretti.

MARTIN, THOMAS L., JR., Professor and Head Department of Electrical Engineering, University of Arizona, Tucson, Arizona. John C. Park, C. R. Hausenbauer.

MEYERHOFF, HOWARD A., Scientific Manpower Commission, 1530 P Street N.W., Washington 5, D. C. M. M. Boring, H. G. Hutton.

MILLER, JOHN L., Assistant Professor, Electrical Engineering, Newark College of Engineering, Newark, New Jersey. Harry S. Dixon, Frederick R. Russell.

MILLER, OWEN WINSTON, Instructor in Industrial Engineering, Washington University, St. Louis, Missouri. D. A. Fischer, G. Nadler.

MILLER, WILLIAM MACKAY, Instructor in Civil Engineering, University of Washington, Seattle, Washington. R. O. Sylvester, J. E. Colcord.

MYKKANEN, DONALD L., Research Assistant Mechanical Engineering, University of Illinois, Urbana, Illinois. Leo Pigage, Irvin L. Reis.

NICHOLLS, GEORGE C., Instructor, Engineering Drawing and Machine Design, University of Colorado, Boulder, Colorado. C. L. Eckel, R. M. Oliver.

OSBORNE, PHILLIP W., Assistant Professor of Mechanical Engineering, Oregon State College, Corvallis, Oregon. M. Popovich, W. H. Paul.

OYAMA, MATSUJIRO, Professor of Electrical Engineering, University of Tokyo, Hongo, Bunkyo-ku, Tokyo, Japan. W. Leighton Collins, T. J. Dolan.

PARKER, JERALD D., Instructor of Mechanical Engineering, Oklahoma A. & M. College, Stillwater, Oklahoma. J. H. Boggs, R. E. Venn.

PARSONS, WALTER HERBERT, JR., Director of Instructions, Academic Division,

The Engineers' School, Fort Belvoir, Virginia. E. E. Pickard, T. E. Jones.

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ZAMPARO, JOSEPH, Assistant Professor of Physics, Manhattan College, New York, New York. Brother A. Leo, Brother G. Kane.

106 new members
275 previously added

381 new members this year

Professor Emeritus **John Clayton Tracy** of Yale University, a member of the ASEE since 1907, died November 1, 1955, in New Haven, Connecticut, at the age of 86. After graduating in 1892 with PhB and CE degrees, he began teaching in the Yale Civil Engineering Department and continued until his retirement in 1936. For 21 years head of the Department, he reorganized both Engineering Drawing and Engineering Mechanics courses. His major contributions to engineering education were made in changing the Sheffield Scientific School from a three-year to a four-year program, and in establishing first a division and later a separate School of Engineering at Yale. Professor Tracy was a Life Member of the ASEE, and member of the General Council 1912–1915 and 1920–1923.

MATHEMATICS IN ENGINEERING

Report of Pasadena Conference

The recommendations given below are the results of an exploratory meeting held on November 28–29–30, 1955. The topics agreed upon will be developed further at an open Summer Institute conference, sponsored jointly by ASEE and the National Science Foundation, to be held at the University of Michigan, Ann Arbor, on June 20–21–22, 1956.

The present rapid developments in the various engineering disciplines are bringing both the research and design engineer into an increasingly intimate contact with new and diverse fields of the mathematical sciences. Since this trend promises to increase steadily with future engineering advances, the role of mathematics in the engineering educational program should be under continual assessment.

A preliminary evaluation of the role of mathematics in engineering was made by a group of 22 engineers and mathematicians at an invitational conference held in Pasadena, California, on November 28, 29, and 30, 1955. This closed conference was sponsored jointly by the American Society for Engineering Education and the National Science Foundation, in cooperation with the California Institute of Technology and the University of Michigan. The organization was effected by a planning committee consisting of Dean George Granger Brown, University of Michigan, Co-Chairman; Dr. Richard S. Burington Bureau of Ordnance, U. S. Navy; Professor Paul F. Chenea, Purdue University; Professor Howard W. Emmons, Harvard University; Dr. George H. Hickox, National Science Foundation; President William V. Houston, The Rice Institute; Dr. Hillel Poritsky, General Electric Corporation; Professor F. C. Lindvall, California Institute of Technology, Chairman.

The participants were chosen by this committee to give as wide a representation of the different engineering and mathematical fields as possible from the academic, research, and industrial points of view. The agenda for the three full days of round-table discussions drawn up by the planning committee included four broad topics:

(a) An interchange of ideas among the engineers on the mathematical trends and requirements in their respective fields.

(b) A review of the interplay between mathematics and engineering, with an evaluation of the role that several new fields of mathematics might come to play in engineering.

(c) Consideration of the present and future mathematical content and philosophy for both undergraduate

and graduate curricula in engineering.

(d) Broad planning of a general open meeting to be held at the University of Michigan in June, 1956, under the joint sponsorship of ASEE and the National Science Foundation to amplify the conclusions reached under items (a), (b), and (c).

Michigan Meeting

The general plan evolved by the conferees for the meeting at the University of Michigan, Ann Arbor, in June, 1956, provides for between six and eight half-day sessions. The sessions will be devoted to the following areas: probability, statistics, numerical analysis and computers, systems analysis and synthesis, and continuum mechanics.

Typical sessions will consist of two invited addresses by outstanding speakers, one of whom is primarily interested in the mathematical aspects of the particular topic, while the other is primarily concerned with the use of that particular field in engineering. The program is designed to stress those areas of mathematics which are finding new uses in engineering, and will emphasize the interaction of the disciplines of mathematics and engineering. It is also hoped that at least one session will be devoted to a panel discussion concerned with the impact of these new fields of mathematics on education for science and engineering students.

The Role of Mathematics in Engineering

In general, it can be said that there are three principal facets of mathematics as applied to the engineering sciences:

(1) The use of mathematical language, structures, and concepts in the expression and formulation of the basic physical laws upon which engineering rests.

(2) The distillation of complex engineering systems and physical phenomena into mathematical models which are descriptive of the engineering systems, and which therefore may be suited to quantitative analysis.

(3) The use of mathematical techniques to carry out quantitative analysis in established models.

It is true that an engineer employs mathematical knowledge and techniques to widely varying degrees, depending on the level of sophistication and needs of his particular work. Nevertheless, it was felt that since the scope of mathematics applicable to engineering is expanding so rapidly, all engineers should possess sufficient "mathematical literacy" to determine more or less in what category difficulties may lie, to know when to turn to a specialist for advice, and to be able to communicate effectively with such persons.

New Fields of Mathematics in Engineering

Certainly classical fields of mathematical analysis such as differential equations, function theory, and the calculus of variations are widely employed in engineering. Moreover, much research remains to be done in these fields, both by the mathematician and engineer, particularly toward the understanding of various phases of nonlinear phenomena in continuum theory.

Despite this, most conferees were more concerned with the appearance of entirely new fields of mathematics in engineering science over the past two decades. The field of mathematical

statistics has become an important adjunct for both the design and test engineer. Probability and the theories of statistical estimation are also finding increasingly significant applications in the fields of guidance and control. The theory of probability, with particular emphasis upon stochastic processes, is now the basis of much of the work in modern electrical and communications design.

The use of probabilistic and statistical models to describe complex engineering systems and to formulate design criteria for such systems is becoming increasingly widespread. The wartime operations research and the former engineering "common sense" have evolved to include broader mathematical structure (e.g., linear and nonlinear programming, theory of games) which has led to certain broad scientific principles for analyzing and synthesizing exceedingly complex engineering systems.

Finally, the advent of high-speed computing machines has given the engineer an important tool, both for engineering analyses and syntheses. It has also given rise to fresh developments in the mathematical field of numerical analysis. In the applications of numerical analysis and computing machines, many of the conferees expressed apprehension about the present and future misuse of high-speed machines, because of the lack of mathematical background and literacy on the part of engineers and applied scientists.

The Teaching of Mathematics to Engineering Students

The calibre and continuity of the high school mathematics preparation are basic to any discussion of the mathematics program for engineering students. The conferees were not willing to accept a policy of lowered admission standards, with remedial work as part of the normal college program. Rather, it was believed that engineering colleges should insist that those students who wish to complete their training in the normal time must come prepared to start a course in calculus and analytical geometry at the beginning of their freshman year. For this, a sound training in the bulk of the material usually covered in a two-year high school algebra course is needed, as well as analytic trigonometry, the basic ideas of plane geometry, and a small amount of solid geometry.

It was also noted that several leading engineering schools no longer required solid geometry for entrance, and that many others are dropping this requirement. It was felt that the usual year spent in plane geometry has not been effectively used and that the course in trigonometry should emphasize the analytical aspects of the subject, with comparatively little emphasis on "solving triangles."

It was considered important that those high school students expecting to major in science or engineering in college should take mathematics throughout their entire last year in high school, as continuity of effort between secondary school and college is exceedingly important. A gap of a year without mathematics seriously handicaps a student who must compete with classmates who are freshly prepared. It is suggested, therefore, that wherever possible high schools should offer four years of mathematics, with the first three-year sequence revised along the lines indicated above. The fourth year could then contain additional algebra, coordinate

geometry, and some elementary calculus. For adequately staffed high schools, too, a college-type course in calculus and analytic geometry could be offered to replace the first year college course.

The objectives of mathematics training in college are threefold:

(1) to give an understanding of the structure of mathematics;
(2) to give an understanding of the interrelation of mathematics with engineering problems;
(3) to develop manipulative skills.

It is primarily the function of the mathematician to give the student some understanding of the nature and structure of mathematics and how mathematics differs from experimental science. The second function is carried out by instructors in science and engineering, who show how problems of science and engineering are formulated in mathematical language, and how the results of solving the mathematical problem are interpreted physically. Manipulative skills can and should be developed in all courses which use mathematics.

With the limited time available in the undergraduate engineering course, and the increasing demand for additional subject matter, it is essential that close liaison be maintained between instructors of mathematics, engineering, and science courses. This liaison should not be confined merely to knowing the topics taught in various courses. The mathematicians must be conscious of the way in which engineers will need to use mathematics, and engineering instructors must understand the point of view of professional mathematicians. In the same way, instructors in the various branches of the engineering sciences must maintain equally close liaison with each other.

Further, experience has shown that a significant number of engineering graduates have forgotten their basic mathematics. Only by continued use can mathematics be made a part of the engineer's effective equipment. Engineering instructors are urged to make maximum use of the students' mathematical preparation in junior and senior engineering courses, as well as accepting the responsibility of introducing new mathematical topics as needed.

Report of the Curriculum Subcommittee (Bowker Committee)

Early in the conference, a subcommittee was chosen to formulate an ideal mathematics curriculum in engineering. Their report follows:

The general trend toward the use of more mathematics in engineering will unquestionably result in additional mathematics courses in graduate and undergraduate curricula. In view of the heavy work load in engineering programs, it is not feasible to recommend any general increase in the number of courses.

Most of the recommendations take the form of elective courses, with the expectation that many areas of engineering will find it desirable to suggest or require them, and adjust other items in the curricula accordingly. An ideal solution would be to include some first year mathematics in the secondary school program, perhaps even a year's college level course in calculus and analytic geometry, and to use the time thus created in the engineering program for additional mathematics.

In addition to specialized advanced courses in the branches of mathematics

important for engineering, the introduction of new material in the basic calculus courses should be under constant consideration. It is difficult to see how much material on statistics can be included, particularly in view of the desirability of close coordination between beginning courses in mathematics and physics.

There are, however, several opportunities in elementary calculus to introduce and stress numerical methods, and these should be fully exploited. As a matter of fact, all applied courses in mathematics should take account of the growing use of mechanical and electronic computers and should put increasing emphasis on numerical techniques.

The single course beyond calculus that we feel should be required of all engineering students is a one-semester course in differential equations. A rudimentary knowledge of differential equations is essential to an understanding of physical laws and is the logical capstone of the calculus. Since this course may be terminal for some students, it should contain enough discussion of the general nature of differential equations to permit a student to identify linear and nonlinear types and to distinguish ordinary from partial differential equations.

It should concentrate, however, on linear ordinary differential equations with constant coefficients (and perhaps include the corresponding difference equations). It should introduce, both as a pedagogical and practical device, some of the standard numerical techniques, which may necessitate the elimination of material on formal integration of special nonlinear types often found in courses at this level. In teaching this course it is important to emphasize the translation from physical to mathematical problems and to interpret the solutions of the differential equations in terms of physical problems.

It is desirable that the students be prepared to take calculus in their freshman year and that they should acquire in secondary school an adequate background for this purpose in algebra, trigonometry, and the use of coordinates. In these circumstances the differential equations course could come in the sophomore year, but, in any case, it should follow calculus immediately.

After differential equations, the next priority should be given to a one-semester course in introductory statistical analysis. Some calculus should be prerequisite. It is the thinking of the Committee that this course will be required of an ever-increasing number of engineering students. Topics would include basic statistical notions: random variables and distribution functions, the general concept of statistical decision-making, standard significance tests and estimates, and an introduction to experimental design. Some material on quality control and sampling inspection should be included.

Our third recommendation is that the mathematical curriculum contain a two-year elective sequence in applied analysis for engineers. Ordinarily a student would take one year as an undergraduate and the second during his first graduate year. The topics in this sequence would include (in some order) vector and tensor analysis, matrices, partial differential equations, special functions, boundary and initial value problems, complex variables, integral transforms, integral equations, and variational calculus.

Two patterns seem to emerge for organizing this material into a two-year sequence. The first starts with a one-year course in advanced calculus for engineers based on one of the standard textbooks, in which almost all the topics listed above are mentioned. The objective of this course is to provide students with mathematical literacy by acquainting them with a variety of mathematical concepts and techniques. The second-year course would then contain a more detailed discussion of some of the same topics.

An alternative pattern is to have separate courses devoted to (1) vectors, tensors, matrices, (2) partial differential equations, (3) complex variables, (4) integral transforms and related topics. The objective here would be to provide a more detailed discussion of individual topics than is possible in a one-year composite course, and to emphasize the development of mathematical ability as opposed to a broad acquaintance with mathematical topics.

A further recommendation deals with the establishment of three one-semester elective courses dealing with newer areas which we believe are likely to be important in the future.

These courses are:

1. Modern computing possibilities, which would include some material on numerical analysis, some on the mathematization of engineering problems, and some on the nature of machine capabilities.

2. Probability theory for electrical engineers, physicists, and possibly for industrial engineers interested in operations research. The course would be at the same level of mathematical sophistication as probability courses frequently offered as part of a one-year sequence in mathematical statistics. For engineering purposes, emphasis on combinatorial probability, finite problems, and manipulations with densities should be reduced in favor of presenting material on discrete and continuous stochastic processes.

3. Maxima and minima of functions for several variables under various kinds of restraints, including systems of linear inequalities. It would contain an introduction to linear programming, as well as its extensions and applications in engineering or logistics. Such a course might be labeled "Optimization in Multicomponent Systems."

The exact outline of these courses is something which needs to be worked out. Except perhaps in the computing field, no standard courses of this sort have come to the attention of the Committee.

The final recommendation is that funds should be found to support well-conceived curriculum construction and experimental textbook writing programs in these three fields.

The following participated in the closed conference on the Application of Mathematics to Engineering: A. H. Bowker, Stanford University; Richard S. Burington, Department of the Navy; Paul F. Chenea, Purdue University; Stephen H. Crandall, Massachusetts Institute of Technology; Howard W. Emmons, Harvard University; W. L. Everitt, University of Illinois; George E. Hay, University of Michigan; F. C. Lindvall, California Institute of Technology; R. F. Mettler, Ramo-Wooldridge Corporation; Morris Ostrofsky, Westinghouse Research Laboratory; Hillel Poritsky, General Electric

Company; William Prager, Brown University; Allen E. Puckett, Hughes Aircraft Corporation; J. R. Ragazzini, Columbia University; L. I. Schiff, Stanford University; R. J. Seeger, National Science Foundation; J. J. Stoker, New York University; C. B. Tompkins, University of California at Los Angeles; A. W. Tucker, Princeton University; J. Harold Wayland, California Institute of Technology; R. R. White, University of Michigan; C. R. DePrima, California Institute of Technology.

HUMANISTIC–SOCIAL SUMMER SCHOOL

Sponsored by: Humanistic-Social Division of ASEE
Dates: June 28–30, 1956
Theme: How Can Humanistic-Social Courses Be Taught Most Effectively?
For information write: Melvin Kranzberg, Associate Professor of Social Studies, Case Institute of Technology, Cleveland, Ohio.
Iowa State Coordinator: James Humphrey, English and Speech Department, Iowa State College, Ames, Iowa.

This program, based on and developing from the *Report of the Humanistic-Social Research Project,* is focused on *specific courses* and *how* these are actually taught in the classroom. Each speaker will describe the course he offers, discussing (1) objectives, (2) content and organization, (3) reading assignments, (4) teaching methods, and (5) effectiveness of the course as given. The program will be of special interest to those engaged in teaching similar courses and to engineering educators concerned with fresh departures in teaching the humanistic-social stem.

Thursday, June 28

Afternoon: History of Science Courses
Henry Guerlac, Cornell University
Carl W. Condit, Northwestern University
Thomas M. Smith, California Institute of Technology

Friday, June 29

Morning: Psychology Courses
M. Carr Payne, Jr. Georgia Institute of Technology
James T. Freeman, Iowa State College

Afternoon: Western Civilization Courses
Louis Furman Sas, The City College of New York
John P. Fife, Stevens Institute of Technology

Saturday, June 30

Morning: American Civilization Courses
Alfred D. Chandler, Massachusetts Institute of Technology
Reginald C. McGrane, University of Cincinnati

THE ROLE OF PHYSICS IN ENGINEERING EDUCATION

The AIP Report—Editorial Note

For several years, calls have been heard and preliminary steps taken toward a re-examination of the relationship between physics and engineering instruction. This need was recognized by the ASEE Committee on Evaluation of Engineering Education, which requested the American Association of Physics Teachers and through them the American Institute of Physics to study the matter. A committee was appointed, and its final report is given in full below. Through the courtesy of Dean Elmer Hutchisson, Chairman of the AIP Committee, and of Editor Robert R. Davis of *Physics Today* (which presented the report in December for the physics group) concurrent publication has been made possible for the ASEE.

The Report of a Committee of the American Institute of Physics

THE REPORT IN BRIEF: The role of physics in engineering education is not a static one. It must respond and evolve with the momentous changes in both engineering and physics which are occurring continually. The predominant reliance of early engineering upon art is giving way to a modern technology based squarely upon the physical sciences. Since the beginning of this century we have seen as much progress in physics as had been obtained in the whole previous history of mankind. Yet the obvious and enormous increase in subject matter of modern physics is not the most significant factor relating to the aim of instruction in physics in the education of engineers. On the contrary, the cardinal aim should be that of imparting to the student a point of view, an attitude of mind, and a capacity to deal with the principles and methods of analysis of contemporary physics, for, without training and experience in these modes of thought, neither physicist nor engineer will prove competent to deal with the emerging problems of science and technology.

In the interest of instilling this point of view with respect to basic principles and to the mastery of methods of approach, the Committee makes the following recommendations which are discussed in detail in the report:

1. Improved communication between engineers and physicists at the institutional level to discuss objectives and determine mutual needs.
2. Early contact of engineering undergraduates with physics.
3. Increased participation of research-minded professors in undergraduate teaching.
4. Introduction of more challenging experiments in laboratory instruction.

5. Greater emphasis, particularly in textbooks of general physics, on ideas, principles, and methods.
6. More appropriate use of mathematics in general physics teaching.
7. Greater encouragement of experimentation in teaching.

Foreword

Presented herein is the final report of a committee established in December 1954 by the American Institute of Physics to study the role of physics in engineering education and to recommend ways of making the teaching of physics in engineering as effective as possible. This committee had its genesis in a request made to the American Association of Physics Teachers (AAPT) by the Committee on the Evaluation of Engineering Education of the American Society for Engineering Education (ASEE), which was appointed in 1952. The ASEE committee has been studying the patterns needed in engineering education to keep pace with the recent rapid developments in science and technology. In this study, the Committee on Evaluation recognized that physics deserves special attention and made a request of the AAPT to appoint a committee for this purpose. In considering this problem, the AAPT concluded that the problem was so broad and of such importance that the American Institute of Physics, representing all physics in America, should be asked to set up the proposed committee. It was expected that the Institute's committee would study and make full use of the results of the joint conferences between engineers and physicists, which had been or were being held on nuclear and solid-state physics, mechanics, thermodynamics, and electrodynamics under the sponsorship of individual universities, the ASEE, and the National Science Foundation. The present Committee was appointed and asked by the Institute to evaluate the teaching of physics in engineering education and to recommend means by which physics teachers could make the maximum possible contribution toward developing the kind of engineers that are needed in the complex civilization in which we find ourselves.

To obtain first-hand information in carrying out its work, members of the Committee in pairs visited 26 representative colleges offering engineering programs and discussed the physics courses within these programs with members of the staffs of both the engineering and physics departments. In addition, questionnaires were sent to the physics departments of essentially all engineering colleges asking for detailed information on the physics courses offered in these schools. Reports of these visits and the replies to the questionnaire, as well as reports of the joint conferences mentioned above, were studied by the members of the Committee. The present report has resulted from two extended meetings of the Committee and from critical discussions on the part of interested engineers.

The Committee takes this opportunity of expressing its deep appreciation to the National Science Foundation for its interest and financial support and to the many engineers and physicists who have given so much of their time in assisting the Committee in obtaining the factual information upon which the recommendations included in this report are based.

The members of the American Institute of Physics Committee on the Role of Physics in Engineering Education are

the following:

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J. W. BUCHTA, Associate Dean of College of Science, Literature, and Arts, University of Minnesota

D. E. CHAMBERS, Manager-Research, Engineering Service Division, General Electric Company

H. L. DRYDEN, Director, National Advisory Committee for Aeronautics

H. FLETCHER, Dean of Engineering, Brigham Young University

W. V. HOUSTON, President, Rice Institute

J. A. HUTCHESON, Vice President, Westinghouse Electric Corporation

R. B. LINDSAY, Dean of the Graduate School, Brown University

D. H. LOUGHRIDGE, Dean, Technological Institute, Northwestern University

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R. J. SEEGER, Assistant Director (Acting), National Science Foundation

F. G. SLACK, Former Chairman Physics Department, Vanderbilt University

L. P. SMITH, Head, Department of Physics, Cornell University

J. A. STRATTON, Provost, Massachusetts Institute of Technology

W. W. WATSON, Head, Department of Physics, Yale University

M. W. WHITE, Professor of Physics, Pennsylvania State University

L. B. BORST, Head, Department of Physics, New York University (*Secretary*)

E. HUTCHISSON, Dean of the Graduate School, Case Institute of Technology (*Chairman*)

I. *The Changing Scene in Physics and Engineering*

Physics and engineering have undergone revolutionary changes during the past century both in their individual development and in their interaction one with the other. The ability of man to profit by and to build on the experiences of the past and to join together in organized cooperative groups has permitted a great expansion of our knowledge and understanding of Nature and also the development and construction of complex machines and structures far beyond anything which would be possible through the ability of any one individual.

The early physicist worked with relatively simple equipment and with concepts based primarily upon his mechanical experience. As a rule he worked with no or few assistants in a small laboratory or at a desk. With such simple resources he discovered the electron, x-rays, and radioactivity and thus opened the door to a flood of new discoveries which are still being announced at an ever-increasing rate in this twentieth century. These new discoveries have been the foundation of entire new industries. The physics of electron flow utilized in the vacuum tube brought forth the vast electronics industry with applications to radio, television, automatic control, and radar. Nuclear fission has resulted not only in new weapons of destruction but in a new power industry as well. These new industries in turn have provided the physicist with powerful new tools, not only to explore the atom, but through improved instrumentation to revive and to accelerate advances in such classical fields of physics as mechanics, thermodynamics, acoustics, electrodynamics, and optics.

Today, although still depending greatly on individuals with deep insight, much of the progress of physics occurs through the strength of organized effort. The physicist draws on the immense resources of other branches of science and of engineering to do his part in advancing understanding and knowledge which at an ever-increasing rate provide new opportunities for engineering application.

The early engineer practiced his profession of building roads, bridges, buildings, as well as "engines" of war, on the basis of empirical knowledge and experience, passed down from generation to generation. Engineering was chiefly an

art with little relation to the science of the time. The ingenuity and talent of these early engineers are evidenced by the great cathedrals, water systems, bridges, and many other structures which are still standing.

Gradually the projects taken on by the engineer widened in scope and complexity and gave rise to an important change in man's way of life, known as the industrial revolution. The engineer built machines to convert the stored-up energy of fuels into useful mechanical energy. Again, much empirical knowledge was gained, but the engineer began to utilize new scientific discoveries and scientific methods of investigation, seeking to establish a rational basis for engineering decisions. New and difficult engineering problems were analyzed into their component scientific problems; the solution thus obtained expanded manyfold the engineer's ability to cope with the increasingly complex requirements of our civilization for machines and structures.

What of the future? In what direction will engineering advance and what kind of emphasis is needed in engineering education to prepare young men to take full advantage of new knowledge being uncovered? These are difficult questions but there are a few guide posts. We do know, for example, that man's power requirements are at least doubling every decade. There is every evidence that this growth in demand will continue and that the engineer will be faced with the necessity for exploiting every possible source of energy to take care of the world's insatiable demand for power. He will need not only to find ways of converting energy from one form to another more efficiently, but will also have to be able to develop new sources of energy such as that from the nucleus, the sun, and possibly even from the waves or the wind.

As a second general guide, it seems inevitable also that man will be demanding continually more delicate and more rapid methods of controlling power. Automatic methods will pervade all branches of engineering. The civil engineer will use automatic methods in tasks ranging from surveying to the great movements of earth and steel that are needed in modern construction. To a greater and greater extent, factories will be automatically operated. The high-speed electronic calculator will supersede the slide rule and, in many cases, elements of the human thought process itself. Inevitably the sanitary, chemical, and metallurgical engineer and all other engineers will rely more heavily on science. The pace of scientific and engineering achievement is now such that obsolescence is a major consideration. Often, the engineer must embark on a long-range project which may be rendered obsolete by ideas or devices now only in the earliest stages of discovery or development. He will make the best decisions who can best evaluate the possible scientific competition.

The physicist in his quest for knowledge often may confine his study to one problem at a time, but the engineer must solve all problems in one integrated design synthesized from his knowledge of many disciplines. The engineer may be called upon to complete a task for which existing knowledge is incomplete or inexact; here he must rely upon judgment based upon long experience. But as knowledge increases and engineering becomes based more squarely upon physical science, the greater the scientific grounding of the engineer, the better his engineering achievement.

Teachers of physics and of engineering, in turn, must adjust their teaching to these continuing changes in physics and engineering. The engineer dedicates his life to improving man's physical well-being and health. His is a creative profession and requires men of ingenuity, resourcefulness, and imagination. The engineer needs a broad understanding of the fundamentals of physics and other sciences whether they have immediate

application or not. He must be able to grasp the implication of new discoveries and the developing concepts of nature and be able to respond to the enthusiasm and stimulation of the creative scientist. Also, he must have knowledge of the course of history and be well trained in the art of receiving, interpreting, and communicating ideas to others. Yet, he must be taught that the engineer is a man of action, a doer, and a builder. To assist in training young men who can carry on these important tasks, the physicist and the engineer must work continually as partners in engineering education.

II. *Physics as it is Now Taught*

As was mentioned in the foreword, the members of the Committee are convinced that a report of this kind to be meaningful must be based upon first-hand information gathered through actual visits to engineering institutions and on-the-spot discussions. The following paragraphs summarize the information obtained from such visits and give a reasonably complete picture of physics as it is now taught in engineering colleges throughout the country. Numerical statistics are given in the Appendix.

The time devoted to physics in the engineering curriculum varies over wide margins. In several strong institutions two years are devoted to a general physics course amounting to as much as 17 to 20 semester hours. In many cases the time assigned to physics has been substantially increased over the past decade and there is an apparent trend in this direction. Nevertheless, the program of physics most commonly found in engineering colleges is a course of 8, 10, or 12 semester hours. The courses with the smaller numbers of credit hours often start in the sophomore year. Three-fourths of the colleges visited or those who replied to the questionnaire fall into this category (see Appendix A).

Mathematical prerequisites for physics vary from none except those required for admission (usually not less than higher algebra in high school) to one or two semesters of calculus. Simultaneous registration in calculus is required in about one-half of the schools from which data were obtained.

Atomic physics or so-called "modern physics" included in the general course averages about 10 per cent of the course. However, there is some evidence that if the numerous up-to-date examples of first principles cited in the several main divisions of physics, but not set apart as modern physics were included, the quoted percentages would be increased. In a few cases the time definitely devoted to modern physics is as much as 25 to 30 per cent.

Two or three hours per week are generally devoted to laboratory work throughout the physics course. Deviations from this pattern are in the direction of less laboratory. Laboratory sections are taught in nearly all schools by graduate assistants under supervision of senior staff members. Lectures are always given by senior staff. Recitations are generally under the direction of mature staff members and are taught both by experienced teachers and advanced graduate assistants. In a number of institutions, a critical study of laboratory instruction is taking place and already several basic changes have occurred which will greatly improve the effectiveness of laboratory instruction.

The objectives of the elementary course as described by the majority of the physics departments are, with only a few exceptions, the teaching of the most general basic physical laws and conservation principles. A fraction (approximately 20 per cent of those visited) emphasized problem-solving and the preparation of students for later engineering

courses. The historical development of science, the presentation of the scientific method, the coordination of mathematics, understanding of physical laws and engineering applications were also mentioned. Unfortunately, too often, the objectives had not been clearly thought through and there had not been enough discussion of these objectives with engineering staff members.

Generally, the engineering departments, when asked, agreed with the first of the above objectives. They wish the elementary physics course to be taught as a self-sufficient scientific discipline without special emphasis on engineering applications except possibly as these are used pedagogically as motivation devices.

An interesting trend is noted in a number of institutions. In some this is represented by new courses under a distinctly new curriculum called Science-Engineering (or Engineering Science) which does not carry the designation of one of the usual engineering divisions. In others, the student is permitted to substitute physics courses for technical engineering courses, thus qualifying him for a science major under one of the usual engineering degrees. In contrast to this trend, in one institution, most of the work in general physics is taught by engineering departments.

III. *A Brief Appraisal of Present Courses*

In the preceding section we have a brief factual view of the physics courses being taught. The important question is, of course, "Are they being well taught?" As with many questions the answer must be both "Yes" and "No." In some institutions physics is very well taught; in others it certainly borders on the inadequate. Also there are parts of some courses which are very well taught and other parts which certainly could be improved. This section of the report attempts to appraise frankly the good features as well as some of the shortcomings of physics courses now being given.

There is widespread dissatisfaction among both physics and engineering faculties with the encyclopedic coverage of the general physics course. This characteristic is often attributed to the extensive coverage of texts even though the teacher could, if he chose to do so, delete large sections from most texts. The desire is frequently expressed for a text with inclusion of basic principles and a minimum number of relevant but unnecessary materials and illustrations. A widespread opinion exists also that the physics program for the engineers should include more atomic, nuclear and solid state physics and that to an increasing extent examples from modern developments in physics be used in the general course. It must be recognized, however, that the amount that can be introduced into the general course will not be sufficient for the engineer whose professional life will extend over the next half century. To include more of the modern developments, there is a growing approval of an additional course, at least one term or semester in length, at approximately the junior level and suitable for the engineer who has completed the general physics course and the parallel mathematics.

In many institutions it is felt that the physics program is not assigned a sufficient fraction of the student's time. It was stressed that the one-year course which is often given is not sufficient for inclusion of the subject matter *all* engineering students should have. The newer topics, particularly, cannot be presented adequately within a one-year course. It is recognized that a reduction in the number of topics covered in the first year will help. But most physics

teachers and even many engineers are convinced that the gain will not be adequate to allow time for the inclusion of many present-day developments. At best the student will be left ill-prepared to comprehend these newer topics.

Unfortunately, the role of laboratory work in physics is often not clearly defined. It is interesting to note that sometimes engineers rated it more highly than the physicists did. If the objectives sought in the laboratory instruction are the development of techniques and the use of measuring instruments, the laboratory is generally considered to be successful. But if, as most teachers believe, it is to be an effective means of teaching principles, then improvement must be attained. The forward-looking experimentation now taking place will be watched with much interest.

Engineers and physicists alike deplore the poor mathematical preparation often obtained by the student in the secondary school. This situation necessarily lowers the mathematical level of basic freshman courses. In some schools an appreciable fraction of the students must take remedial mathematics, thus spending time that should be utilized for other purposes. In any case, it is recognized that the appreciation of mathematics as a physical tool must be supplied or at least be enhanced by the physicist.

In many institutions the members of the Committee found a great interest in, and really first-rate teaching of, physics for engineers. In others there is certainly room for improvement. Interestingly enough, improvements which the Committee would suggest and which form the basis for the recommendations in this report are not those which are sometimes mentioned in discussions between engineers and physicists. For example, there is no evidence of less interest today in expounding both the classical as well as the newer physics than existed decades ago. The great expansion of research in new fields has not caused the physicist to overlook the classical areas of physics in his teaching. In fact, this very expansion makes it imperative that from time to time we reexamine our teaching in terms of our present-day objectives. Only thus can we fulfill adequately our obligation to engineering education.

A large majority of engineering departments visited preferred to have the physics taught by the physics staff. In this way the student can best be exposed to the points of view and the methods characteristic of a basic science with its primary goal of understanding nature.

In a number of schools the engineers complain about the inadequacy of the preparation of the student who enters the first course in engineering mechanics, electricity, or thermodynamics. This may be an example of the almost universal complaint which is made at all levels that the previous training of the student is inadequate. Surely it can be helped by those teaching the advanced courses if they will take the necessary pains to assist the student in transferring to later courses the knowledge and understanding which he has gained from previous courses. However, to the extent that it is justified with respect to physics and engineering it may be due to uninspired teaching, poor organization, inappropriate texts, insufficient time, deficient preparation of the student, or a combination of all of these. If any of these are at fault then, indeed, do we have a common problem to be discussed between engineers and physicists and to be solved in a sympathetic and effective manner.

Communication between the various engineering departments and the physics department often is not adequate. It is generally agreed that both formal and informal meetings of all those staff members who are doing the teaching will provide an invaluable exchange of information of the course content and of the level of the performance of the students which is sought, expected, or actually attained. Such meetings are highly desirable and

will yield returns in a better curriculum and understanding of mutual objectives and problems. Such meetings do not presume a dictation of content of course material, nor of a method of teaching by one group for the other. Each department should be the final arbiter in its own realm but the increased knowledge and the comments of the others may give a better background for a decision. The appreciation by the physicist of his contribution to engineering would be enhanced by the exchange of points of view with engineers but it is not suggested that this lead to the teaching of engineering in the physics classes or to the teaching of physics in the engineering departments.

IV. *A Set of Goals for Physics in Engineering Education*

Perhaps the most important contribution that physics can make to the training of engineers is to provide a knowledge and appreciation for (1) the methods that have been found effective in describing the way nature behaves and (2) the concepts that have been derived therefrom. The body of physics as we know it today, which is considered essential to an understanding of these principles and concepts, represents the distillation and unification of knowledge gained over the past. The point of view of many physicists has been, and now is, that one should acquire an understanding of natural phenomena irrespective of any practical application. Such a view point has been eminently worthwhile since most modern technological developments are direct applications of many of these principles that were once considered academic and without practical use.

It is our belief that an increasing segment of the population and particularly those trained in technical fields should have an appreciation for the science of physics and the mode of thought which to such a large degree has been responsible for the phenomenal development of physics over the past decades. Specific contributions which the physicist can, by virtue of his training, make to the education of an engineer are:

(1) The physicist is, almost by definition, curious about the physical world in which he finds himself. It is hoped that some of this curiosity, and some of the satisfaction and enthusiasm resulting from increased understanding, will be imparted to his students.

(2) Along with understanding, the physicist also learns the limitation and scope of his descriptions and interpretations. These often are of a different character from those which the student meets in the solution of classroom problems in engineering and yet an appreciation of them is an essential part of an engineer's education.

(3) He has learned that there are underlying, unifying principles that can be rigorously expressed in mathematical terms and which are very general in their application. He has found these to be powerful tools in the expression and solution of important problems in nature. Examples of such principles are the laws of the conservation of energy and momentum which he teaches to his students with emphasis on where they apply and on their limitations.

(4) He knows that to appreciate fully the physics of today the student must know something of the historical development of underlying ideas, of the struggles of the past and the great strides that were taken by a few individuals in enunciating these broadly applicable unifying principles. We are firm in our conviction that all engineering students should know something of the origin of the knowledge which they will use so continuously.

(5) The physicist has often pioneered in the development of precise methods of measment. This he has done to understand nature better and to place his concepts on as firm a base as possible. Thus he, more than other men, has been interested in determining the fundamental constants of nature with the highest possible precision.

(6) The physicist believes that through a proper understanding of the laws of nature, people can arrive at more objective judgments and, it is hoped, keep free of many of the popular fears and superstitions involving science itself today. The history of physics has given ample proof that this can be done and certainly should be one of the objectives of a physics course.

(7) Lastly, a precise understanding of the basic concepts of physics is perhaps the best guarantee that the presently trained engineer will be able to contribute to the technology of tomorrow and herein lies one of the most important contributions the physics teacher can make in engineering education.

Only a partial achievement of the above goals can be expected in any single physics course under the best teacher. Certainly, a one-year course in general physics from a modern viewpoint, utilizing calculus as an essential aid, is hardly adequate. The trend away from too great a dependence upon the practical arts and toward the sciences in engineering practice makes it highly desirable to consider a two-year general physics course for all engineers. To teach properly the principles discussed above, the content of the general physics course must be carefully screened to eliminate much of the material of an engineering or applied nature. Furthermore, to achieve an understanding of and a feeling for the way nature behaves, a challenging set of laboratory experiments should accompany this general physics course. Routine "cook-book" experiments should be kept to a minimum.

We also recognize that one of the goals of physics instruction should be an introduction to the basic principles underlying atomic and nuclear physics and the solid state. The one- or preferably two-year general course must be regarded only as a preparation for introductory modern physics courses which may be given at the junior-senior level. A thorough understanding of nuclear and solid-state physics is achieved only through years of intensive study at the graduate level.

V. *Recommendations—a Program for Achieving the Goals Set*

In recommending a program aimed at more effective physics teaching in engineering education, the Committee recognizes that primary effort must occur at the local level and stem from within the colleges themselves. It is incumbent upon physicists to recognize the changing character and needs of engineering. The predominant reliance upon art is giving way to a modern technology based squarely upon the physical sciences, and this is reflected in the growing demands of the engineering profession for both a deeper understanding of fundamental principles and a broader introduction into recent advances. Physicists would do well to view these demands with sympathy and understanding and to accept them as a challenge to wider influence rather than as an invasion of vested interests.

It is no less important that the engineering profession and, indeed, physicists themselves take account of the evolving character of physics. The obvious and enormous increase in subject matter of modern physics is in our judgment not the most significant factor relating to the aim of the physics instruction in the education of engineers. On the contrary, we believe the cardinal aim to be that of imparting to the student a point of view, an attitude of mind, and a capacity to deal with the principles and methods of analysis of contemporary physics, for without training and experience in these

modes of thought, neither physicist nor engineer will prove competent to deal with the emerging problems of science and technology.

In the light of these comments we make specific recommendations under the several headings listed below:

1. Improved Communication

In each local institution members of the departments of physics and engineering should meet frequently together for free discussion in order that they may come to understand and appreciate more clearly their common interests and mutual needs. In some of the leading engineering schools it has been demonstrated that the contribution of physics, together with chemistry and mathematics, to the education of the engineering student can be greatly enhanced when the student clearly sees for himself that subsequent engineering courses draw upon the basic principles of the sciences and make use of the power of analysis developed from the point of view of the physicist. In these cases there is very little trouble with the problem of motivation. On the other hand, it is deadly from the standpoint of a student's motivation and morale if the engineering teacher assumes "a priori" that he must completely reteach his subject from the beginning even though it has been covered to a certain point in the basic sciences. It is urged, therefore, that teachers of engineering, wherever possible, provide an opportunity in their courses for the students to deal with engineering situations as best they can, using the understanding and methods obtained from the basic sciences. This cannot be done unless there is free exchange of information and views between the teachers of basic science and engineering; consequently, this constitutes one of many reasons why it becomes imperative to cultivate this close association.

2. Early Contact with Physics

We attach the utmost importance to instilling the point of view expressed earlier with respect to basic principles and to the mastery of methods of approach, and it is for this reason rather than any question of course content that we urge strongly that engineering students at an early point in their undergraduate careers be brought into an association with those who have made physics their life work.

3. Research-Minded Teachers for Undergraduates

Traditionally the home of research in the physical sciences has been the science departments of our colleges and universities. Much of the research that has led to the changing concepts and expanding scope of physics has been the work of members of the staff of such departments. Their research is essential to the continuing advance of science. The challenge of research promotes continuing vitality in those who engage in it and thus contributes to the development of science.

In recent years, however, there has been a growing tendency among some staff members engaged in research to neglect a basic responsibility which they share with the other members of their department, namely, the teaching of undergraduate students. This leads, we believe, to several undesirable effects.

Firstly, the high degree of motivation and inspiration which the successful research man can give is denied the undergraduate student.

Secondly, the undergraduate student is not provided with the high level of instruction which the research-minded professor is capable of giving.

Finally, such a professor, no longer required to refresh his understanding of the broad developments in physics, may tend to become increasingly narrow in his point of view.

In view of these facts we urge that consideration be given this problem to the end that all members of the staff, including those engaged in research, be encouraged to give instruction in physics to the undergraduate student. We firmly believe that in this way not only will the department provide the highest type of instruction in physics, but also the department will maintain its highest proficiency in research.

4. Laboratory Instruction

Since the fundamental laws and principles of physics provide the means of understanding many basic phenomena of nature, it is important that the student of science and engineering become acquainted first-hand with these basic phenomena in the laboratory and by means of well-chosen demonstration lectures. It is in the laboratory that the student comes into actual contact with phenomena in a basic way and, indeed, has the closest association with his teacher. Consequently, it is here that the teacher is presented with a great opportunity to aid the student in obtaining a clear and realistic understanding of basic physical principles. This opportunity should not be wasted by requiring the student to do unchallenging, stereotyped, and superficial experiments. "Efficient" operation in the sense of obtaining maximum data from standardized equipment should not be the goal of laboratory instruction. Rather, great effort should be expended to provide a type of laboratory instruction which will lead the student partially to discover a particular law or principle by his own efforts. This presents a challenge and allows the student to contribute to his own learning process. A law or principle arrived at in this way will not easily be forgotten and the more able student will appreciate its deeper significance. In this way the laboratory experience can contribute most forcefully to the student's assimilation of basic physical principles. It is, therefore, recommended that teachers of physics continue to give serious thought to the improvement of laboratory instruction in basic physics. In a few schools very significant results have already been achieved.

5. Textbook for General Physics

Since the educational arrangement of one teacher for each student which many consider ideal is rarely feasible, and since students cannot usually be trusted to take adequate notes on lectures, no matter how carefully delivered, the textbook will long continue to be the primary medium in the education of students, particularly in a science like physics, which demands close and repeated study.

Examination discloses that though the number of general physics texts available for students of engineering is relatively large, some of them tend to be marred by numerous shortcomings which undoubtedly lower the efficiency of the educational process. Among these are the following:

(1) There is a tendency to put too much stress on facts and too little on fundamental *ideas, principles,* and *methods.* Some textbooks pay too little attention to the methodology of physics and hence give the student little idea of the manner in which physics progresses or even of the limits of present knowledge.

(2) As a corollary to (1), some texts provide too little encouragement for the student to reason things out for himself and to test his understanding of principles and methods. There are, in general, too many problems of the simplest substitutional variety that may be used by teachers to the exclusion of the more thoughtful items.

(3) There is often too little care and imagination in the *selection* of material from the standpoint of fundamental significance and hence the books tend to be far too long and encyclopedic in character. Moreover, they appear to be growing longer. Books of 800–900 pages seem too long for the general physics course unless the assignments by the teacher are very skillfully made to eliminate certain sections.

(4) In too many cases recent developments in physics are tacked on at the end instead of being thoroughly integrated into the general development. In particular there is frequently little consideration of the fundamental role of the theory of relativity and quantum theory in the *evolution* of classical physical ideas.

(5) The mathematical methods used in texts often underestimate the intellectual capacity and interest of the student. Elementary differential and integral calculus, vector analysis, and modern mathematical concepts should be used whenever they aid in the concise rigorous formulation of principles or problems; thus the student will become accustomed to such methods and gain confidence in their use.

It is very likely that no single physics text will satisfy all teachers or any one teacher for all time. The fact that a few of the existing texts have been adopted by a large number of teachers gives evidence of the high regard with which these texts are held. Nevertheless, some members of the Committee are still seeking the "perfect" text that would be free from the objections listed above. The text for general physics that they visualize would be considerably shorter than most existing texts. It would preferably be written by a teacher who has a strong research interest, or by a group of such persons; but if by one person, he should be one who has thought a good deal about the methodology of physics and is willing to develop the subject in unconventional fashion. Such texts in special fields are now actually being written at one large institution.

6. Mathematics in General Physics Teaching

Since mathematics in the form of the calculus is the natural language of physics, it is desirable that the student should get acquainted with it early in his college career and that the general physics text should use it freely. In many institutions an introduction to the calculus is given simultaneously with general physics. In others, beginning physics is delayed so may be noted that the one-year sophomore that preliminary work in calculus may precede the first semester of physics. It is obviously very important that the physics teacher should continually stress the use of mathematics in expressing the ideas of physics. At the same time it is essential that he emphasize the physical meaning of all results obtained by mathematical analysis so that the student will not get the mistaken idea that physics is merely a collection of mathematical symbols.

The above recommendation in many instances raises problems in the teaching of elementary college mathematics. The mathematics teacher quite reasonably desires to develop in his students an *understanding* of mathematics and its meaning as a form of human activity and looks with justifiable suspicion on the teaching of mere manipulation. The physics teacher, therefore, has the responsibility to effect a gradual transition from mathematical philosophy as taught in the mathematics department to the use of mathematics as a tool as required in physics, just as the engineering teacher has the responsibility to effect a similar transition from physics as a basic science to the use of the principles of physics in solving engineering problems. To provide these transitions in a sympathetic and effective manner requires the utmost cooperation between the mathematicians, physicists, and engineers.

7. Encouragement of Experimentation

An impartial appraisal of the quality of instruction in American colleges and universities in both the sciences and engineering will reveal a distressing amount of teaching of a completely pedestrian sort. The prevalence of such mediocre efforts should not, however, conceal the fact that there are also many gifted and effective teachers and that interesting and rewarding experiments for the improvement of laboratory and classroom instruction are taking place in many institutions. It is our impression that a

wider knowledge of such experiments and innovations would encourage similar efforts and that an exchange of views would be beneficial to all concerned. Consequently, we urge that the appropriate journals of the American Institute of Physics and also the JOURNAL OF ENGINEERING EDUCATION take steps to give wider publicity to experimentation in teaching, to "case histories" of new approaches to laboratory instruction, and to similar endeavors.

The various conferences encouraged and supported in recent months by the National Science Foundation for the discussion of such topics as mechanics, thermodynamics, electrodynamics, solid state, and nuclear physics in engineering education have served a highly useful purpose by affording opportunities for the exchange of views among leaders of specialized fields. We believe that the organization of similar conferences from time to time in the future will be profitable to both engineers and physicists.

Recent meetings of the AAPT and of the Physics Division of the ASEE have had sessions devoted entirely to the teaching of general physics to engineers. We urge that meetings of this kind be continued and that whenever possible further joint meetings be held. Such meetings, by bringing together researchers and teachers, physicists, and engineers to share their experiences, their faiths and their hopes, will do much to stimulate further interest and understanding of the role of physics in engineering education.

Appendix

Summary of Information Obtained from Questionnaires

As stated previously, early this year there were sent to the physics departments of some 180 colleges, offering programs in engineering, questionnaires concerning the physics courses taken by the engineering students. To date replies have been received from about 120 colleges and the following summarizes the answers to questions on the general courses, the advanced courses, emphasis on research in classical physics, and changes in courses now being planned.

A. General Physics Course

Physics instruction to engineering students is limited to the general physics course only, in 46 per cent of the colleges. This course is required by almost all engineering schools as an integral part of the curriculum. Data derived from the questionnaires in regard to some details of the General Courses are given in the paragraphs below.

1. *The number of semester hours and the distribution of time devoted to lecture, recitation, and laboratory vary with the school.*

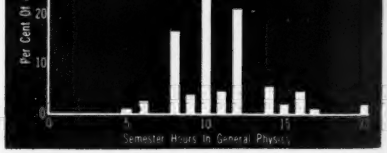

FIGURE 1

Figure 1 shows graphically the number of semester hours devoted to general physics as related to the number of colleges. It

may be noted that the one-year sophomore physics course of 10 semester hours is most popular. In many schools a two-year general course requiring up to 20 semester hours is taken by all or most engineers.

2. *Prerequisites for the general physics course for engineers.* Figure 2 shows graph-

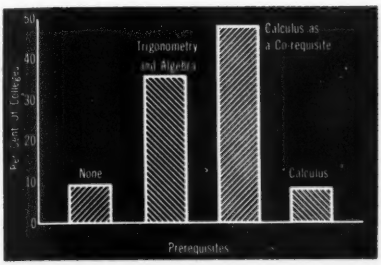

FIGURE 2

ically that calculus is usually required as a co-requisite for this course and that at least algebra and trigonometry are required prerequisites in almost all instances.

3. *Percentage of time in general physics devoted to "modern physics."* Figure 3

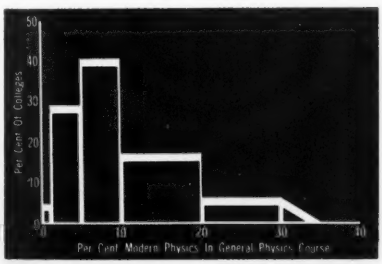

FIGURE 3

shows roughly the stated amounts of "modern physics" included in the general course. Although contemporary physics is concerned with fluid dynamics, thermodynamics, microwaves, and many other modern topics, the term "modern" as used here refers to atomic, nuclear, and solid-state physics. It is, of course, difficult to define just what is modern and just what is classical so that the answers can be considered only as qualitative judgments. The answers given range from very little in a few instances to more than 30 per cent at Princeton University. In most cases this treatment of modern topics is distributed throughout the course but in about one-third of the colleges it is concentrated, usually, at the end of the course.

4. *Texts used in general physics.* Five texts predominate and are used by 75 per cent of the colleges. Some fifteen different texts are used by the remaining quarter of the colleges, many in only one college each.

B. Advanced Courses

In more than 50 per cent of the colleges reporting, additional physics is taken by some of the engineering students, usually as an elective. The most common additional course is one in modern or atomic physics which is taken in about 35 per cent of the colleges. As many as 325 engineering students take this course at Pennsylvania State University. The average engineering registration in advanced courses is about 30 students. Three or four different texts are popular, but a dozen others are used in one or more schools.

C. Research Interest in Classical Physics

There has been much discussion of the present-day interest of physicists in research on problems in classical physics in comparison with the widely publicized research in "modern" physics. Actually this comparison has no direct relation to the teaching effectiveness in general physics since the same critical understanding of fundamental concepts required in classical physics is basic to competent research in "modern" physics as well. Furthermore, the same point of view and attitude of mind so important to good physics teaching is present no matter in what particular branch of physics a man's research is being done. Unfortunately, there are no simple means

by which research can be reliably measured so that, although a question on this matter was included, the reader must recognize the limited reliability of such a survey. The replies indicated that 58 per cent of the colleges, all of which offer engineering education, reported research completed recently or in progress by their physics departments in mechanics, acoustics, heat or thermodynamics, electricity and magnetism, or optics. These research projects are divided as follows:

TABLE I

Field	Number of Research Projects	Number of Published Papers
Mechanics	32	24
Acoustics	23	14
Heat and Thermodynamics	30	23
Electricity and Magnetism	41	32
Optics	40	34
Totals	166	127

TABLE II

	Projects
17 colleges report research in one classical field only	17
14 colleges report research in two fields	28
15 colleges report research in three fields	45
14 colleges report research in four fields	56
4 colleges report research in five fields	20
64 Total	166

D. Changes in Physics Courses

About one-half of the physics departments specifically state that changes are being considered or planned. The most common change is the inclusion of more atomic, nuclear, and solid-state physics in the general physics course, frequently in the time provided by a reduction of engineering examples or application. About 10 per cent of the colleges are adding a course in modern physics, including atomic, nuclear, and solid-state physics, as a junior-senior elective for engineers.

OAK RIDGE INSTITUTE SECONDARY SCHOOL COURSE

The Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tennessee, has announced a new program to assist secondary schools in science teaching. Sponsored jointly by the National Science Foundation and the United States Atomic Energy Commission, the program will enable a selected group of high-school teachers to attend a three-month course at Oak Ridge. The group will then spend nine months traveling and giving lecture-demonstrations for science classes at high schools throughout the country. The results of this experiment will be used by the NSF to plan and support future programs aimed at increasing the number of young people choosing careers in science and engineering.

SECTION MEETINGS

Section	*Location of Meeting*	*Dates*	*Chairman of Section*
Allegheny	Carnegie Institute of Technology	April 27–28, 1956	J. W. Graham, Jr., Carnegie Institute of Technology
Illinois-Indiana	Purdue University	May 12, 1956	O. W. Witzell, Purdue University
Kansas-Nebraska	University of Wichita	Oct. 26–27, 1956	J. K. Ludwickson, University of Nebraska
Michigan	Wayne University	May 5, 1956	G. H. Howell, Wayne University
Middle Atlantic	Bell Telephone Laboratories, Murray Hill, N. J.	May 12, 1956	C. C. Carr, Pratt Institute
Missouri-Arkansas	St. Louis University	April 7, 1956	W. P. Armstrong, Washington University
National Capital Area	Capital Radio Engineering Institute, Wash., D. C.	Oct. 11, 1955	D. C. Jackson, Jr., Aberdeen Proving Ground
New England	Tufts University	Oct. 19–20, 1956	W. S. Evans, University of Maine
North Midwest	South Dakota State College	Oct., 1956	J. W. Howe, State University of Iowa
Ohio	Ohio State University	April 27–28, 1956	E. C. Clark, Ohio State University
Pacific Northwest	University of Washington	May 10, 11, 12, 1956	J. B. Morrison, University of Washington
Pacific Southwest	University of Arizona	Dec. 28–29, 1956	R. G. Moses, Pasadena City College
Rocky Mountain	Denver University	April 28, 1956	W. H. Parks, University of Denver
Southeastern	Tulane University	April 5, 6, 7, 1956	D. W. Dutton, Georgia Institute of Technology
Southwest	Texas Western College	March 30–31, 1956	H. K. Bone, University of Oklahoma
Upper New York-Ontario	Syracuse University	Oct. 12–13, 1956	B. H. Norem, Syracuse University

Members of the Society are welcome at all Section Meetings

Members have requested that the application blank be reproduced more often, so that it could be available for potential new members. Accordingly, it is printed below.

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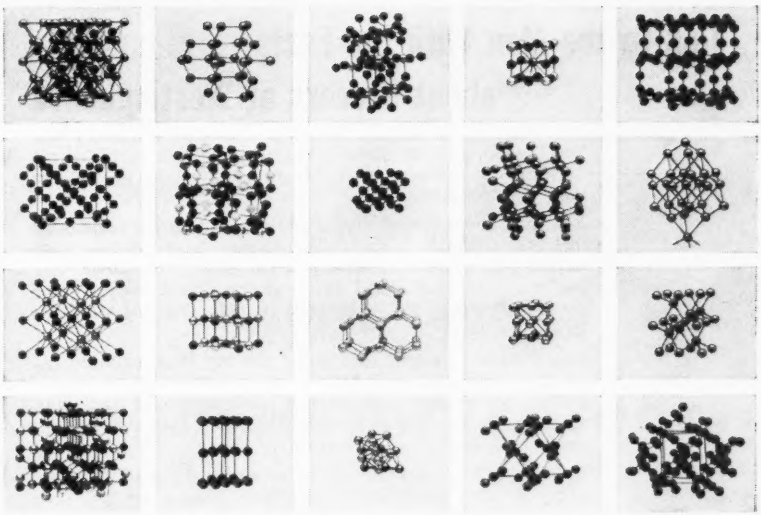

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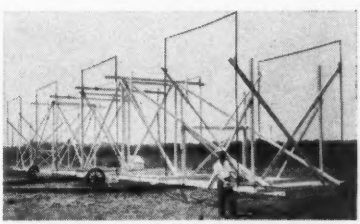

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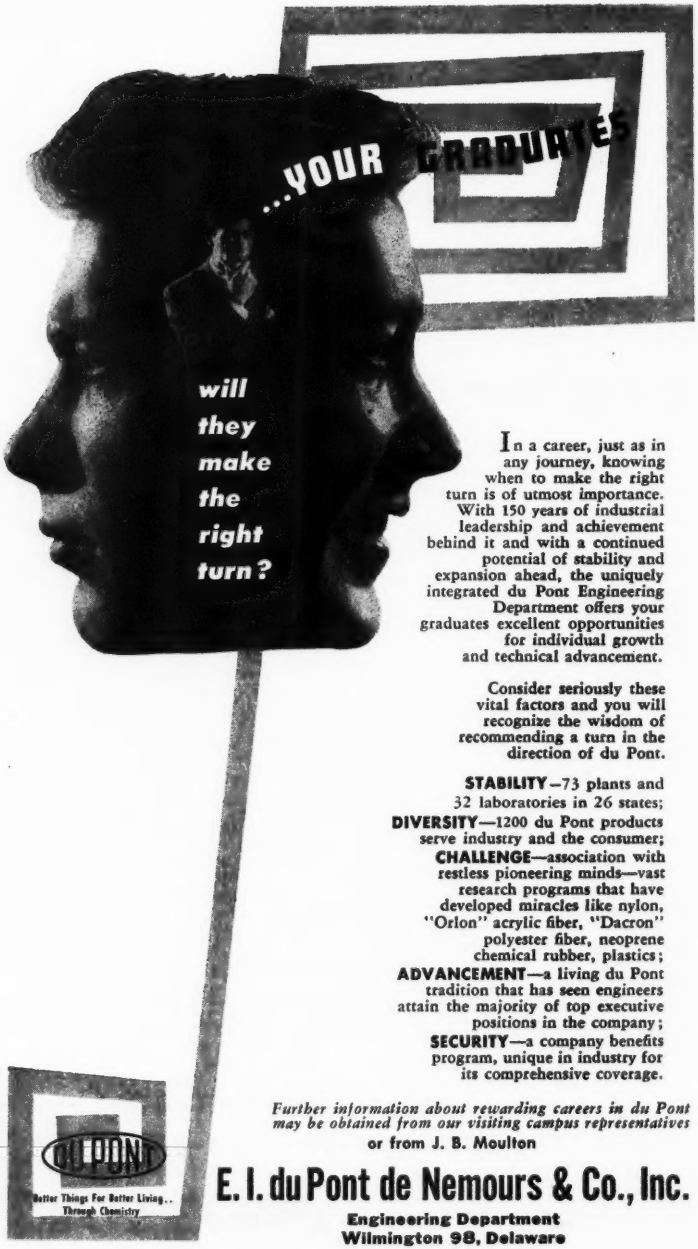

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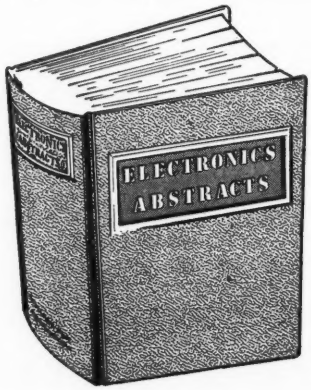

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